REPORT NO. CASD-NAS-74-046
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LIFE SCIENCES PAYLOAD DEFINITION AND INTEGRATION STUDY

VOLUME I • EXECUTIVE SUMMARY

GENERAL DYNAMICS
Convair Division

REPORT NO. CASD-NAS-74-046

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MAJOR ACRONYMS AND SYMBOLS

ARC	Ames Research Center
BEST	Bioexperiment Support & Transfer
CER	Cost Estimating Relationship
CDMS	Command and Data Management Subsystem
COL	Carry-On Laboratory
CRT	Cathode Ray Tube
CVT	Concept Verification Test
EC/LSS	Environmental Control/Life Support Subsystem
ECG	Electrocardiogram
ECS	Environmental Control System
EEG	Electroencephalogram
E.I.	Equipment Item
EMG	Electromyogram
ESE	Experiment Specific Equipment
FL	Flight
FPE	Functional Program Element
G&A	General & Administration
GFE	Government Furnished Equipment
GPRE	General Purpose Research Equipment
GSE	Ground Support Equipment
HQTRS	Headquarters (NASA)
IMBLMS	Integrated Medical & Behavioral Laboratory Measurement System
JSC	Johnson Space Center
K	One Thousand (e.g., $K or Kbits)
LBNP	Lower Body Negative Pressure
LSPS	Life Support & Protective Systems
M	One Million
MSFC	Marshall Space Flight Center
NR	Non-recurring
R	Recurring (cost)
RAM	Research Applications Module
R-O	Recurring Operations (cost)
R-P	Recurring Production (cost)
SEB	Source Evaluation Board
SRT	Supporting Research & Technology
SSPDA	Space Shuttle Payload Development Activity
VCG	Vectorcardiogram
WBS	Work Breakdown Structure

SUMMARY

The Life Sciences Payload Definition and Integration studies are an integral part of current NASA planning activity to define potential research laboratories for the Shuttle Spacelab. This report documents the last in a series of three closely related studies which together describe requirements, analytical work, and design concepts for a family of Life Sciences Laboratories. Total program history from its initiation through the current study is shown in Figure 1.

BACKGROUND

The first of these three studies performed under Contract NAS8-26468 during 1970-1972 drew heavily on guidance from NASA and consulting scientists. The scientists were surveyed to aid in selecting an inventory of life sciences research functions and related equipment necessary to accomplish space research goals. In compiling the inventories of functions and equipment, mission parameters and other constraints were purposely not imposed so that comprehensive baseline inventories could be obtained. Research requirements, as defined by the scientific community, were broad in scope to encompass research in medicine, biology, life support and protective systems, and man/systems integration. The research was grouped by categories rather than by specific experiments to provide planning flexibility. A general philosophy of the laboratory "facility" approach was used in the conceptual designs generated. The four preliminary conceptual designs selected from this effort are characterized as:

a. Maximum Laboratory. A reference baseline providing full life sciences research capability.

b. Maximum Nominal Laboratory. Foreseen as the most comprehensive laboratory that could be flown with the space station complex.

c. Minimum-30 Payload. Applicable to an initial space station mission as well as to a 30-day Shuttle Sortie flight.

d. Minimum-7 Payload. To operate in a 7-day Shuttle Sortie flight.

These payloads encompass a range of capabilities from full capability to respond to all research goals down to lesser capability payloads with defined reductions in facility weight, volume, power, and cost for defined reductions in scientific responsiveness.

The second study was performed under Contract NAS8-29150 during 1972-1973. This study employed several of the smaller laboratories from the previous study to determine compatibility with the Shuttle Sortie module concept. Initial activity involved updating functional capabilities and related equipment items of the laboratories as directed by the NASA Life Sciences Payload Integration Team. The second task established size

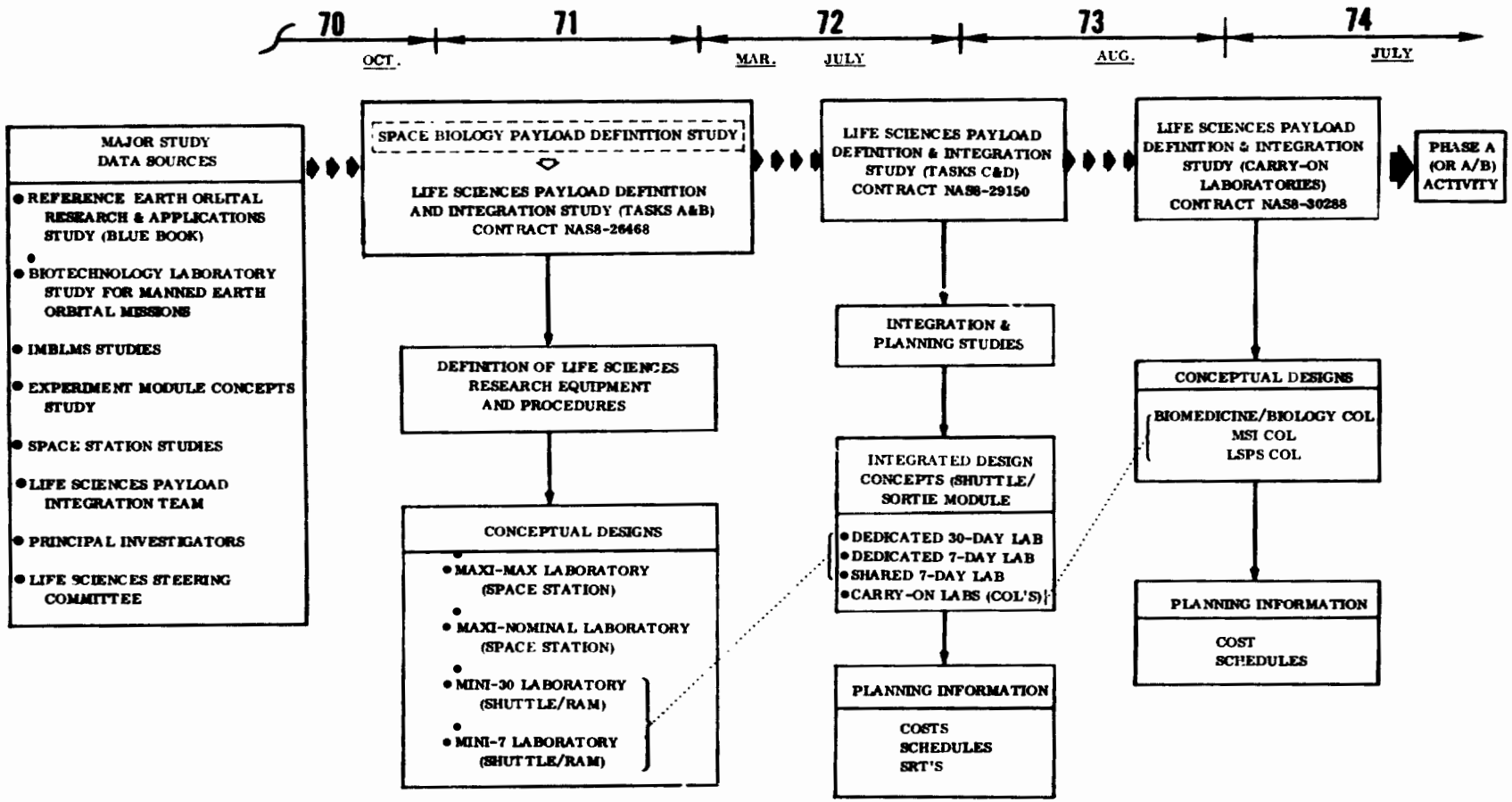

Figure 1. History of Life Sciences Payload Definition and Integration Studies

and characteristics of the various Sortie module subsystems (e.g., electrical power, environmental control/life support) required to support the defined research capability of the baseline laboratories. Additional activity included determination of equipment costs, development schedules, and significant supporting research and technology requirements associated with the laboratory development. This study also generated conceptual designs of smaller, portable, essentially self-contained Carry-On Laboratories (COLs) that could be employed in a multiple-purpose Sortie laboratory or in the crew compartment of the Sortie Orbiter. The work performed to this point defined three additional tasks necessary to develop the required data base for pre-Phase A program planning: 1) a more comprehensive study of COL design concepts, 2) in-depth cost analysis of selected concepts, and 3) in-depth analysis of data management requirements.

CURRENT STUDY

The third and current study was performed under Contract NAS8-30288 from mid-1973 through mid-1974. This task was directed by an updated set of guidelines provided by the NASA Life Sciences Steering Committee. Research priorities were modified in the updated guidelines to enable application of new insight regarding research requirements as disclosed by Skylab experience. Also, the laboratory/spacecraft interface guidelines were updated to reflect new information obtained from the European Space Research Organization Spacelab program. To meet these guidelines, analysis and design activities were conducted to expand the data base in three task elements defining COL design concepts, Dedicated Laboratory program cost requirements, and Dedicated Laboratory data management requirements. These task elements are reported under Parts I, II, and III of this volume.

Within the Element 1 task, design concepts were defined for several categories of COL payloads ranging from 23 to 318 kg (50 to 700 pounds). The data defining these COL designs, development schedules, and costs was taken to the same level of detail as for the larger Shared and Dedicated Laboratories of the prior studies. This data was assembled to permit future comparative studies of program costs and schedules to determine alternative approaches to meet the research goals. Program options include an incremental growth mode of facility development employing aggregations of COLs (Figure 2) versus the alternative approach leading to the same laboratory functional capability in a single concentrated development program.

The cost analysis (Element 2) was aimed at applying low cost approaches to the development of laboratory costs. The 30-Day Dedicated Laboratory, as defined during the previous study (NAS8-29150), was updated by the Life Sciences Working Group during August 1973 and used as the costing baseline. The approach was the same as that used for the cost analysis tasks of the COL (Element 1).

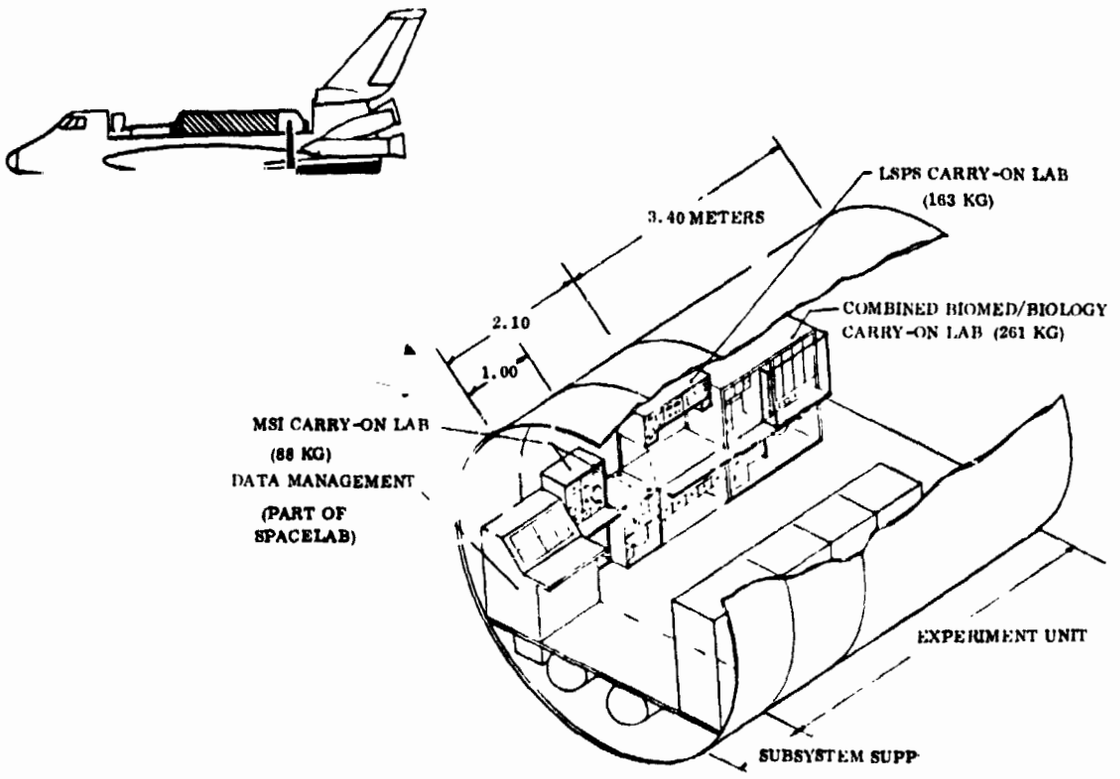

Figure 2. COL Concepts Sharing Uncommitted Portion of tl · celab

Element 3 involved re-evaluation of the data management requirements for the 30-Day Dedicated Laboratory. The task included a review of the Life Sciences command and data management system (CDMS) requirements for the updated baseline laboratory and the compatibility of these requirements with the CDMS capability.

PART I

TASK ELEMENT 1

CARRY-ON LAB DESIGN CONCEPTS

SECTION 1

INTRODUCTION

Study guidelines for the COL activity (Element 1) were defined by the NASA Life Sciences Payload Integration and Steering Committees. These guidelines included a comprehensive set of space research mission requirements obtained from the scientific community to ensure that the scientists' needs were maintained and the program was directed to allow scientific requirements to drive design responses. Design guidelines were also provided at the outset to stress cost-effective approaches to achieve the scientific goals. The original guidelines were updated as required to incorporate new insight obtained from the ongoing Skylab, Shuttle, and Spacelab operational and planning efforts. Some pertinent COL guidelines are shown in Tables 1-1 and 1-2 to illustrate the comprehensive interaction between the scientific community, NASA coordinators, and industry team employed throughout this program. Other guidelines are discussed where they apply in the following sections.

The COL study was divided into four major tasks:

Task A - Identification of research requirements of the COLs. This included definition of research areas and functions to be supported as well as the potential equipment needed to support the desired research.

Task B - Development of a number of conceptual layouts for the COLs based on the research and equipment defined during Task A. These potential COL designs were reviewed by NASA and several favored concepts were selected for the final design and integration studies to follow in Task C.

Task C - Analysis of COL integration parameters and development of final conceptual designs for the selected COLs.

Task D - Development of COL planning information, including design drawings of a selected COL to permit the fabrication of a functional breadboard of that COL. Other planning information included definition of COL/Spacelab interface data, cost data, and program cost schedules.

These tasks are all dependent on an accurate definition of general purpose research equipment needed in the COLs. For example, the conceptual and breadboard designs rely heavily on the equipment to be incorporated in these designs, and the generation of cost data is a direct function of the specific equipment to be designed, developed, or purchased. Also, the study of integration and interface characteristics of the COLs will depend on the equipment incorporated therein. For these reasons, equipment specification data was compiled early in the study and updated throughout. The specifications for all equipment items contained in the final COLs are contained in Volume III of this report.

Table 1-1. Guidelines for COL Definition

MINIMIZE ON-BOARD ANALYSIS — MAXIMIZE GROUND ANALYSIS

MAXIMUM USE OFF-THE-SHELF EQUIPMENT

EMPHASIZE MODULAR DESIGNS & COMMONALITY

BASELINE CARRY-ON LAB IS FOR 7 DAYS — DETERMINE Δ'S FOR 30 DAYS

COMMAND & DATA MANAGEMENT SYSTEM PROVIDED BY SPACELAB

COL INTERFACES TO SUPPORT EXPERIMENT SPECIFIC EQUIPMENT
(I.E., LBNP, ROTATING LITTER CHAIR, PRIMATE HOUSING UNIT,
RADIATION SHIELDING, ETC.)

DESIGN GUIDES

MANPOWER AVAILABILITY: 2 HRS/DAY (BASELINE) - FULL TIME

WEIGHT:
CATEGORY A LABORATORIES OF 227 TO 318 KG (500-700 LB)
CATEGORY B LABORATORIES OF LESS THAN 91 KG (200 LB)
CATEGORY C LABORATORIES OF LESS THAN 23 KG (50 LB)

SIZE: MODULES TO FIT THROUGH A 40 INCH HATCH

POWER: NONE ESTABLISHED — DESIGN TO DETERMINE

Table 1-2. Guideline Documents for Biomedicine Biology COLs

1. MEMO TO NASA CENTERS LIFE SCIENCES PAYLOAD INTEGRATION STUDY STEERING COMMITTEE FROM ROBERT W. DUNNING, SUBJ: DISCIPLINE PRIORITY GUIDANCE FOR CURRENT LIFE SCIENCES PAYLOAD INTEGRATION STUDY (MSFC/NAS8-29150), JULY 25, 1972.

2. "PLANNING GUIDANCE FOR IDENTIFICATION AND LAYOUT OF LIFE SCIENCES 'CARRY-ON' PAYLOADS FOR SHUTTLE SORTIE MISSIONS," AUGUST 9, 1972.

3. MEMO TO ROBERT W. DUNNING FROM S. P. VINOGRAD, M.D., SUBJ: CANDIDATE RESEARCH FUNCTIONS FOR "CARRY-ON MINI-LAB", JULY 25, 1973.

4. MEMO TO ROBERT W. DUNNING FROM S. TOM TAKETA, SUBJ: CANDIDATE RESEARCH FUNCTIONS FOR SHUTTLE CARRY-ON MINI LAB CONFIGURATION," AUGUST 23, 1973.

5. "SKYLAB AND THE LIFE SCIENCES," NASA-MANNED SPACECRAFT CENTER, FEBRUARY 1973.

6. "BIOMEDICAL EXPERIMENTS AND SYSTEMS IN SKYLAB," NASA-MANNED SPACECRAFT CENTER, APRIL 1971.

7. "SURVEY OF TECHNIQUES USED TO PRESERVE BIOLOGICAL MATERIALS," E. J. FEINLER & R. W. HUBBARD, STANFORD RESEARCH INSTITUTE (CONTRACT NAS2-6201), JANUARY 1972.

8. FINAL REPORT, "REQUIREMENTS STUDY FOR A BIOTECHNOLOGY LABORATORY FOR MANNED EARTH-ORBITING MISSIONS - PHASE II, VOLUME I: DESCRIPTION OF REQUIREMENTS," MC DONNELL DOUGLAS ASTRONAUTICS COMPANY-WEST, REPORT MDC G0620 (CONTRACT NAS1-9248), JULY 1970.

9. IMBLMS PHASE B-4 REPORTS, BOTH GENERAL ELECTRIC & LOCKHEED MISSILES & SPACE CO.

10. TASK A&B, FINAL REPORTS, GENERAL DYNAMICS CONVAIR AEROSPACE DIV., NAS8-26468, MARCH 1972.

11. TASK C&D, FINAL REPORTS, GENERAL DYNAMICS CONVAIR AEROSPACE DIV., NAS8-29150, AUG. 1973.

SECTION 2

RESEARCH AND EQUIPMENT REQUIREMENTS FOR CARRY-ON LABORATORIES

The NASA Steering Committee generated prioritized list of research categories for medical, biological, MSI, and LSPS research in COLs. These research categories guided selection of equipment to be packaged in the laboratories.

2.1 BIOMEDICINE/BIOLOGY RESEARCH AREAS AND EQUIPMENT SELECTION

Biomedical, vertebrate, and cell and tissue human-emphasis research objectives provided by the NASA guidelines were grouped under the general title, Research Objectives for Biomedical and Biomedical-Surrogate Carry-On Laboratories (Table 2-1). This grouping was chosen to emphasize the dual role played by vertebrate and cell and tissue space research in meeting overall space research objectives. One role would be achieved by research at the subcellular and cellular level of animals, with cells and tissues serving as man-surrogates to accomplish man-related studies that could not be performed directly on human subjects. The second very important role served by the same vertebrate and cell and tissue laboratories is to enable comprehensive basic science investigations directed toward a better understanding of the vertebrate and cell and tissue disciplines within their own right. To emphasize the basic science role, additional vertebrate and cell and tissue research objectives are shown in Table 2-2.

Category C COLs emphasized the research listed under Group 1. The Category B COL supported research in Group 1 and Group 2. The Category A biomedicine/biology COL designs considered all research areas listed in Table 2-1.

These research requirements were used to guide selection of procedures and equipment from the comprehensive inventories generated in earlier phases of this program. Table 2-3 illustrates how various vestibular function research options were used to define compatible hardware requirement options. This basic approach was used throughout the study to develop candidate equipment lists to satisfy all research objectives listed in Table 2-1. An initial list of equipment items for the biomedicine/biological FPEs was formulated and used for the initial conceptual design layouts. This equipment list was refined and updated throughout the study. The final equipment listing for the biomedicine/biology Category A COL is presented in Table 2-4.

2.2 MAN/SYSTEMS INTEGRATION (MSI) RESEARCH AREAS AND EQUIPMENT SELECTION

Only he Category A size guideline was specified by NASA for the MSI COL design concepts. The research areas and equipment requirements for MSI COLs were defined by NASA. The MSI experiments (research areas) are:

Table 2-1. Research Objectives for Biomedical and Biomedical Surrogate COL Missions

BIOMEDICAL/*VERTEBRATES	*CELLS & TISSUES
Group 1	Biochemical Properties
Vestibular Functions (highest priority)	Biophysical Properties
Body Fluid Composition and Electrolyte Functions	
Cardiovascular Functions	Radiation Effects
Group 2	Morphology
Hemodynamic Functions	
Blood Morphology Functions	
Blood Chemistry Functions	
Group 3	
Gastrointestinal Functions	
Excretory Functions	
Pulmonary Functions	
Microbiology Functions	
Neurology Functions	

PRIORITY ↓

*Parallel biomedical research objectives to study basic mechanisms of man's adaptation to the space environment.

Table 2-2. Basic Science Research Areas for Vertebrate, Cell and Tissue, Plant and Invertebrate COL Missions

VERTEBRATES	CELLS & TISSUES	PLANTS	INVERTEBRATES
GROWTH	GROWTH	GROWTH	GROWTH
DEVELOPMENT	DEVELOPMENT	DEVELOPMENT	DEVELOPMENT
REPRODUCTION	METABOLIC STUDIES	METABOLIC STUDIES	METABOLIC STUDIES
EMBRYOGENESIS	HOST-PARASITE RELATIONS	BIOCHEMICAL PROPERTIES	BIOCHEMICAL PROPERTIES
SENESCENCE & AGING	GENETICS	MORPHOLOGY	MORPHOLOGY
GENETICS	RADIATION/HZE PARTICLE EFFECTS	EMBRYOGENESIS	EMBRYOGENESIS
RADIATION HZE PARTICLE EFFECTS		HOST-PARASITE RELATIONS	RADIATION/HZE PARTICLE EFFECTS
		GENETICS	
		RADIATION HZE PARTICLE EFFECTS	

Table 2-3. Research Options and Requirements for Vestibular Function – Basic Mechanisms Causing Disturbance

VESTIBULAR FUNCTION RESEARCH OPTIONS	REQUIREMENTS/MEASUREMENTS/EQUIPMENT	REMARKS
•REPEAT SKYLAB EXPT. M 131		
PERCEPTUAL ACUITY IN SPACE	ROTATING LITTER CHAIR	TOO HEAVY FOR CARRY-ON LABORATORY. CAN BE USED AS "EXPERIMENT SPECIFIC".
ORIENTATION IN SPACE	TEST GOGGLES	CAN BE USED FOR SEMIQUANTITATIVE MEASUREMENT WITHOUT ROTATING LITTER CHAIR.
SUBJECT SUSCEPTIBILITY TO REFLEX DISTURBANCE (CORIOLIS)	MOTION SICKNESS INDEX	CAN BE USED BY TRAINED OBSERVER.
•VESTIBULAR SYSTEM HABITUATION		
PREFLIGHT CREW TRAINING N.A.M.I. SEQUENTIAL HEAD TURN EXERCISES	GROUND FACILITY	SKYLAB CREW PREFLIGHT PREPARATION HAS NOT PREVENTED VESTIBULAR DISTURBANCES IN SOME CASES. NEW TECHNIQUES MAY BE REQUIRED.
IN-FLIGHT N.A.M.I. SEQUENTIAL HEAD TURN EXERCISES	OCULOGYRAL ILLUSION MEASUREMENT DEVICE	OCULOGYRAL ILLUSION BOX CAN BE PROVIDED IN CARRY-ON LAB.
•ACUTE FUNCTIONAL LABYRINTHINE DISTURBANCE (E.G., DILATION OF ENDOLYMPHATIC SYSTEM - MENIERE'S SYNDROME)		
DISTURBED PRESSURE GRADIENTS BETWEEN BLOOD, INTERSTITIAL & LYMPH FLUID COMPARTMENTS	BLOOD PRESSURE COLLOIDAL OSMOTIC PRESSURE PLASMA PROTEINS — M112 BLOOD ELECTROLYTES - M071	
COMPENSATORY DIURESIS & ALTERED BODY FLUID COMPARTMENT VOLUMES & CELL MEMBRANE DIFFUSION GRADIENTS	ANGIOTENSIN ALDOSTERONE URINE COMPOSITION & VOLUME RADIOISOTOPE TRACER STUDIES — M073 BLOOD GAS CHANGES BLOOD PH & BUFFER RESERVE CHANGES	SKYLAB-AUTOMATED SAMPLE PROCESSING FOR PRESERVATION -70°C FREEZER FOR BLOOD, (PLASMA & FORMED ELEMENTS) -20°C FREEZER FOR URINE, WILL ENABLE RETURN OF SAMPLES FOR TESTS SHOWN
SIGNS & SYMPTOMS - VERTIGO - NYSTAGMUS - PAST POINTING - NAUSEA, VOMITING, ETC.	TRAINED OBSERVER WITH PHYSICAL EXAMINATION KIT & LOG BOOK MOTION SICKNESS INDEX	CAN BE PROVIDED IN CARRY-ON LABORATORY.

Table 2-4. Category A Biomedicine/Biology COL Equipment Item Weight, Volume and Power

E.I. NO.	EQUIPMENT ITEMS (E.I.'S)	WEIGHT FOR 7-DAY MISSION, KG	VOLUME, DM^3	POWER, WATTS
C6	*AIR PARTICLE SAMPLER	2.6	0.9	50
C188	AUTO. POTEN. ELECTROLYTE ANALYZER	9.1	131	100
C189	BLOOD SAMPLE PROCESSOR CENTRIFUGE	12.7	25	100
C30A	*CAGE, SMALL VERTEBRATES (8 INCL.)	18.4	88	72
C38	*CAMERA, VIDEO, COLOR	7.7	6.2	69
C34	CAMERA, 35MM	2	2	0
C156	COUPLERS (12 INCL.)	2.4	6	24
C55A	*CREW MOBILITY AIDS	2.3	2.8	0
C55B	CREW RESTRAINTS	4	10	0
C192	DISPLAY, NUMERIC	2	4	2
C167B	DRY STORAGE CONTAINER (ROOM TEMP)	0.5	3	0
C196	EQUIPMENT RESTRAINTS	0.5	1	0
C80	FREEZER, GENERAL	7	15	50
C81	FREEZER, LOW TEMPERATURE	7	15	400
C103	*HOLDING UNIT, SM. VERT.	13.6	188	0
C198	*INCUBATOR, 37C (MINI)	5	8	5
C200	*KIT, ANIMAL PHYSIOLOGY	1.5	2	0
C106A	*KIT, CLEAN-UP	1.5	5	0
C113	*KIT, GENERAL TOOL	4.5	14.2	50
C106	KIT, HEMATOLOGY	4	6	0
C108	*KIT, HISTOLOGY	1	1	0
C110C	KIT, HUMAN PHYSIOLOGY	3	8	0
C110	*KIT, MICROBIOLOGY	2	3	0
C114A	*KIT, MICRODISSECTION	1	2	0
C110B	*KIT, VERTEBRATE MANAGEMENT	3	6	0
C202	*LAMP, PORTABLE HI INT. PHOTO	6.3	6	150
C116	LOG BOOKS	0.5	0.4	0
C91	*MASS SPECTROMETER	11.3	16.4	30
C126	*MICROSCOPE, COMPD	11	28	50
C126A	*MICROSCOPE, DISSECTING	9	28	63
C203A	OCULOGYRAL ILLUSION BOX	0.2	1	0
C132	OSCILLOSCOPE (BATTERY POWERED)	1.6	2.4	0
C149G	RADIOISOTOPE TRACERS	0.3	0.5	0
C153	RECORDER, VOICE (BATTERY POWERED)	1	0.4	0
C83	REFRIGERATOR	5	17	15
C153B	*SENSORS, MISCELLANEOUS	2	2	4
C206	*SHROUD, DEBRIS CONTAINMENT	4.5	300 (depl.)	0
C165	*STERILIZER, TOOL (BACTECINERATOR)	1	1	110
C177	TEMPERATURE PROBES	0.3	0.4	0
C180	TIMER; EVENT	0.2	0.2	0
C48	*VACUUM CLEANER	2.3	10	100
C193	*VENTILATION UNIT, SMALL VERT.	9.5	19	40
C181G	WASTE STORAGE CONTAINER	1	28.3	0
C174	*WATER TANK, ORGANISM (WET WT.)	4.6	22	0
C208	WIRE AND CABLE	2	4	0
C209	WORK SURFACE, AIRFLOW	5	6	75
	RESEARCH EQUIPMENT TOTALS	196.9 (434 LB)	1046.1 (36.94 FT^3)	1559
	PLUS THE WEIGHT OF: RESEARCH EQUIPMENT MODULES	64		0
	TOTALS	260.9 (575 LB)	SEE DRAWING	1559

*E.I.'S NOT INCLUDED IN CATEGORY B & C BIOMEDICAL COL'S.

1.* Effects of Space Flight Environment on Sensory Processes.
2.* Effects of Space Flight Environment on Psychomotor Functions.
3. Cargo Handling Capabilities.
4. Assembly, Deployment, Maintenance, and Repair Capabilities.
5. Attached Teleoperator Manual Controllability.
6. Free-Flying Teleoperator Remote Controllability.
7. Effects of Spaceflight Environment on Individual and Group Dynamics.
8. Locomotion and Restraint Capabilities.
9. Effectiveness of End Effector Designs.
10. Off-Duty Activity and Facilities.
11. Evaluation of Miniature Accelerometers as Motion Sensors to Assess the Effects of Stress and Fatigue.
12. Urine and Feces Collection, Measurement, and Sampling System.
13. Inflight Determination of Bone Mineral Content.
14. Compact Respiratory Measurement Systems.
15. Automated Clinical Chemical Analyzer.
16. System to Preserve Biological Materials.
17. Medical Aspirator.
18. Intravenous Fluid Administration Device.
19. Blood Cell Counter.

The NASA definition also listed the research functions required to perform these experiments. The equipment required for each function was identified and an initial list complied for use in conceptual design layouts. In establishing this list, certain criteria were used to comply with the COL philosophy. Factors considered included: 1) low cost and use of existing or off-the-shelf equipment where possible, 2) simplicity of the methods of performing the required functions and yet maintenance of scientific validity, 3) use of common equipment where possible, and 4) maximum use of facilities aboard the Spacelab e.g., data management equipment. The resulting list of equipment was grouped according to the general functions of:

a. Behavioral Measurements.

b. Data Management.

c. Audio-Visual Measurements.

d. Physiological Measurements.

e. Experiment Specific Functions.

The behavioral measurements group contained the equipment required to measure sensory and psychomotor processes. Data management equipment provided most equipment for automatic or operator control of the experiments, display of experiment

*These two experiments were de-emphasized because of an updating of the list which was performed during the study.

procedures and stimuli, and recording of appropriate results. All equipment in these two groups was developed during the IMBLMS program and was expected to require little modification for use in the COLs. Audio-visual measurements equipment provided the capability for non-interference studies of individual and group dynamics as well as astronaut performance studies where task completion times or body motions were the primary measurements. Physiological measurements equipment is used when the physiological status of the test subject is to be monitored, such as energy expenditure during various cargo handling procedures. The experiment-specific group of equipment will depend on the experiment(s) to be completed on a given mission.

These equipment groups were used in initial MSI conceptual design layouts. During final COL definition, only the audio-visual equipment and some data management equipment were retained.

2.3 LIFE SUPPORT AND PROTECTIVE SYSTEMS (LSPS) RESEARCH AREAS AND EQUIPMENT SELECTION

The sizing guideline used for the LSPS COL was specified as Category A by NASA. Areas of research to be performed for LSPS were divided into 12 categories. These are essentially types of experiments and are listed in order of priority, as established by NASA at the beginning of this study:

1. Water Recovery Methods and Components.
2. Waste Management Methods and Components.
3. Protective Clothing and Advanced Space Suit Assemblies.
4. Carbon Dioxide Collection Methods and Components.
5. Advanced Cooling System Methods and Components.
6. Atmosphere Supply Methods and Components.
7. Advanced Two-Gas Atmosphere Supply and Control Subsystem.
8. Advanced Trace Contaminant Control and Monitoring Subsystem.
9. EVA Suit and Biopack.
10. Food Storage, Preparation, and Feeding Methods.
11. Oxygen Regeneration Methods and Components.
12. Whole Body Shower.

The method used in establishing the equipment for these research areas involved the determination of the functions needed to support the research and the following selection criteria.

a. Analysis of specimens was to be performed on the ground, subsequent to the flight where possible. (For example, water and solids analysis for constituents as well as for micro-organisms would be performed on the ground. If inflight analysis was to be performed, it was assumed to be provided as part of the test apparatus. For example, if water conductivity or pH was to be measured, these sensors were assumed to be included in the test apparatus rather than in the COL.)

b. Data management functions and equipment were assumed to be provided by the supporting spacecraft data management subsystems.

c. The electrical power subsystem was assumed to be provided by the supporting vehicle.

d. Coolant was assumed to be provided by the supporting vehicle.

e. Equipment for experiments involving nuclear radiation was assumed to be a part of the test apparatus and not the LSPS COLs.

f. Equipment and electrical power for lighting in the general vicinity of the COLs were assumed to be provided by the supporting vehicle.

As a result of reviewing the equipment required for each experiment category and of considering the types of experiment apparatus to be tested, four potential groups of COL equipment emerged:

a. Liquid-Handling Apparatus Test Equipment.

b. Crew Interfacing Apparatus Test Equipment.

c. Gas-Handling Apparatus Test Equipment.

d. Feeding System Test Equipment.

The liquid-handling and gas-handling test equipment was practically identical. This equipment would be incorporated into a test bench for general support of tests on liquid- or gas-handling LSPS devices. Such devices might include reverse osmosis units, stills, evaporators, gas-liquid separators, heat pipes, pyrolyzers, incinerators, sterilizers, CO_2 concentrators, and CO_2 reduction units. The crew interfacing tests would differ from the liquid- and gas-handling equipment tests in that a crewman would be involved integrally, such as in testing a urinal. A test bench could be used, but an area for the test of experiment-specific equipment would be better. Such equipment might include commodes, hard or soft pressure suits, clothing, or portable life support units. The feeding system test equipment shared some similarity to both liquid-handling and crew-interfacing test equipment. A crewman would be involved integrally in some of the tests, and a test-bench type structure is required to accommodate the crewman as he tests the feeding devices. Typical test items include food trays with integral temperature control, liquid dispensers, special crew restraints for eating, utensils, food debris cleanup devices, etc.

SECTION 3

CARRY-ON LABORATORY CONCEPTUAL DESIGNS

The design activity began with the generation of 26 candidate COL conceptual layouts for biomedicine, biology, MSI, and LSPS. From these, NASA selected three for final conceptual design and requested conceptual designs for several small biomedical COLs. The 26 candidate layouts are discussed briefly and the final designs are described and illustrated in detail.

3.1 COL CONCEPTUAL DESIGN LAYOUTS

Many COL layout parameters were considered during this study. Several layouts were often drawn for the same FPE using different parameters to obtain varying configurations for comparison. The layout parameters considered for each FPE are summarized in Table 3-1.

Table 3-1. Layout Parameters Considered During Task B

FPE	Layout Parameters				
	Module Configuration, Standardized Rack or Custom	Crew Interface, Standing and/or Seated	Isolation from the Crew, Glove Box, Open, etc.	ECS, Open to Crew Compartment or Closed	Organism Holding Unit Size, Standardized or Custom
Biomedicine	x	x	x	x	
Vertebrates	x	x	x	x	x
Cells & Tissues	x	x	x	x	x
Invertebrates	x	x	x	x	x
Plants	x	x	x	x	x
MSI	x	x			
LS/PS	x	x			

As shown in the first column, two general module configurations were considered: Standardized Rack refers to the placement of COL equipment within racks or consoles with a standard cross-section of 0.61 by 0.61 meter (2 by 2 ft), whereas Custom refers to shapes tailored to suit the individual FPEs. Crew Interface options refer to the orientation in which the crew would generally address the COL: Standing refers to an erect orientation with foot, leg, or waist restraints and Seated refers to a restrained, seated-like position that may be desirable when performing tasks in which the crewman must be very steady (microscopy, etc.).

The last three columns list parameters that apply only to the biology FPEs. Isolation from the Crew refers to the ways in which the COLs could achieve separation of the organisms from the crew atmospheric environment during organism handling procedures. Isolation could be achieved with a transparent, flexible, glove box with arm slots or gloves used for organism access. Another optionwould be to merely have the system open to crew atmosphere. ECS refers to the type of organism ECS assumed for each layout. The open type uses air from the crew compartment for the organism, and the closed system uses its own air processing equipment. Standardized holding unit size refers to the use of a standard size independent of the individual FPE needs but based on an across-the-board evaluation of the requirements of all biology FPEs. The standard holding unit size adopted was based on the cage module in the concept verification testing at NASA/MSFC, and will accommodate eight rat cages. Custom sized refers to the use of holding units tailored to the specific needs of each FPE.

3.2 FINAL BIOMEDICAL/BIOLOGY COL CONCEPTUAL DESIGNS

As discussed in Table 1-1, the NASA guidelines specified that biomedical COLs were to be defined in three sizes, denoted as Categories C, B, and A.

3.2.1 CATEGORY C BIOMEDICAL COL CONCEPTS. The research areas considered during definition of the small Category C COLs included vestibular functions, body fluid composition, electrolyte functions, and cardiovascular functions. Three COLs were conceived to cover the pertinent spaceflight aspects of these research areas. Biomedical Category C COL No. 1 was designated C_1, and was intended to support real-time electrolyte studies and vestibular function research. The major equipment item in this COL is the automated potentiometric electrolyte analyzer currently being developed by NASA/JSC. This analyzer will ultimately be capable of measuring pH, CO_2, O_2, Na^+, K^+, Cl^-, Ca^{++}, and glucose in blood and urine. Other equipment items in C_1 include a blood acquisition kit, urine acquisition kit, physical examination kit, equipment restraints, oculogyral illusion box, and a voice recorder. COL C_1 weighs 22.7 kg (50 lb) and occupies three of the standard sized 36 by 43 by 51 cm crew compartment stowage volumes: two for the automated potentiometric electrolyte analyzer and one for the remaining kits and other equipment. A concept of the package for the kits is shown in Figure 3-1.

COL C_2 was conceived to perform body fluid composition and electrolyte functions research. Major equipment includes the blood sample processor centrifuge developed for Skylab, a blood acquisition kit, and a -70°C freezer for preservation of blood for delayed ground analyses. This COL was intended to complement and reinforce the in-flight bioassay performed by COL C_1. COL C_2 will fit into two of the standard sized stowage compartments, and weighs 22.7 kg (50 lb).

COL C_3 provides for urine collection and return to ground for analysis to complement the blood analysis resulting from COL C_2. It also has provisions for some cardiovascular and vestibular research. Major equipment includes a -20°C freezer, urine

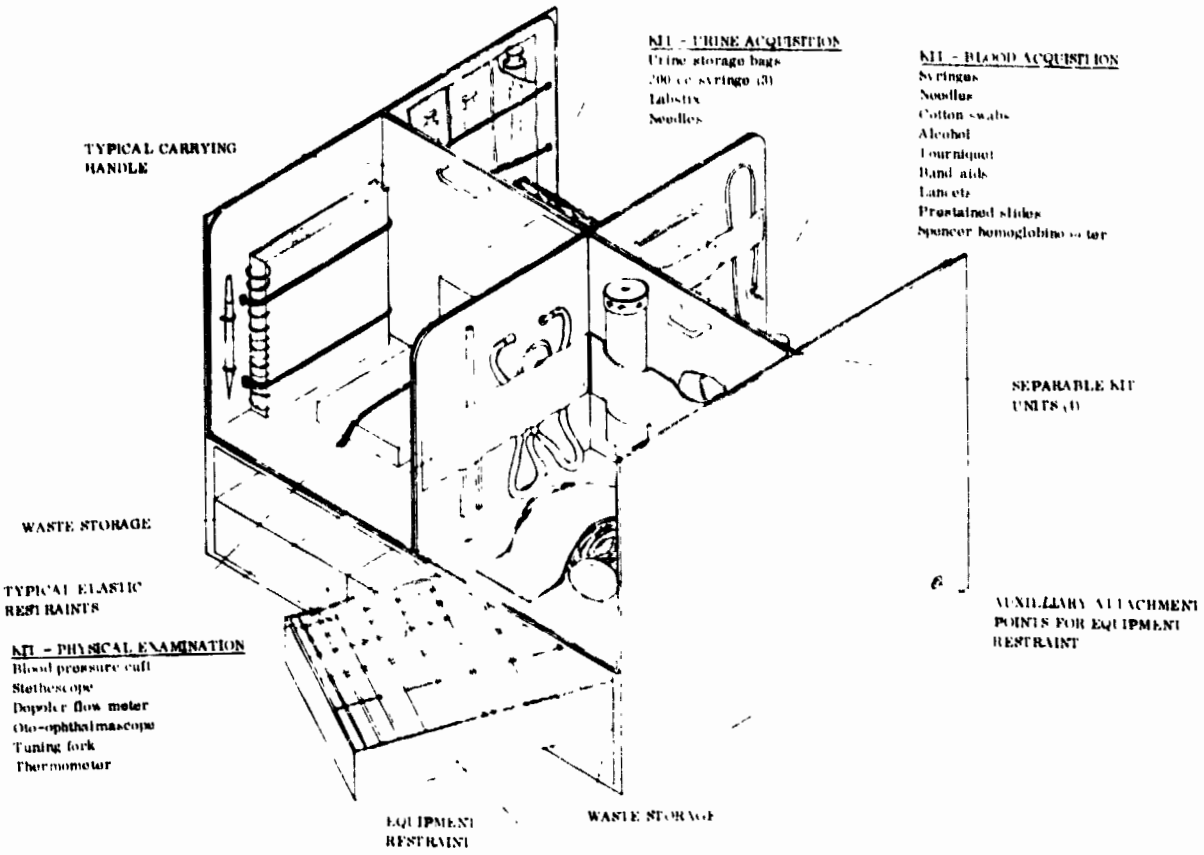

Figure 3-1. Biomedical COL C_1 Conceptual Design Sketch

and blood acquisition kits, and ECG and VCG measuring equipment. COL C_3 weighs 22.1 kg (49 lb) and will fit into one of the standard sized stowage compartments.

As mentioned earlier, Category C COLs were intended to complement each other. Since research in the areas of vestibular, body fluid, electrolyte, cardiovascular, and related functions and adaptations would ideally be performed simultaneously, Category C COLs should be flown together, if possible, especially C_2 and C_3. Combinations of Category C COLs and their properties are summarized in Table 3-2.

Table 3-2. Biomedical Category C COL Combinations

CATEGORY C CONCEPT	WEIGHT KG	POWER W	NUMBER OF MODULES 36×43×51 CM	RESEARCH MISSION EMPHASIS					
				VESTIBULAR FUNCTIONS	BODY FLUID & ELECTROLYTE FUNCTION				CARDIO-VASCULAR FUNCTIONS
					BLOOD		URINE		
					FLIGHT	GND	FLIGHT	GND	
COL_1	19.5	25	3	X	X		X		
COL_2	22.9	425	2			X			
COL_3	19.0	41	1	X				X	X
$COL_1 + COL_2$	42.4	450	5	X	X	X	X		
$COL_1 + COL_3$	38.5	66	4	X	X		X	X	X
$COL_2 + COL_3$	41.9	466	3	X		X		X	X
$COL_1 + COL_2 + COL_3$	61.4	491	6	X	X	X	X	X	X

3.2.2 CATEGORY B BIOMEDICAL COL CONCEPT. Research areas to be supported by the Category B COL were essentially those used in designing Category C COLs. Hence, the same equipment was selected for use. Since the allowable weight of the Category B COL was 91 kg (200 lb), all Category C equipment could be used. The Category B COL equipment can also support some of the Group 2 NASA research areas (hemodynamic, blood morphology, and blood chemistry functions). Major equipment items included in the COL are a blood gas analyzer, the blood sample processor centrifuge, general and low-temperature freezers, various kits, an oscilloscope, a voice recorder, and a refrigerator. The blood sample processor centrifuge and the -70°C freezer provide for return of sufficient plasma and blood sample material to support investigations of both the Group 1 and Group 2 research areas. The -20°C freezer will preserve urine specimens for subsequent ground analysis. The Category B COL weighs 84.7 kg (187 lb) and occupies approximately 380 dm^3 (ft^3) of rack volume.

3.2.3 CATEGORY A BIOMEDICINE/BIOLOGY COL CONCEPT. The Category A COL (Figure 3-2) was to weigh between 227 and 318 kg (500 to 700 lb) and was the most important COL resulting from the current study. The Category A biomedicine COL, selected by NASA to be carried through to conceptual design, provided capability to support small vertebrates as well as biomedical research. This COL contains all essential biomedical equipment contained in Category B and C COLs, plus other equipment for more extensive biomedical research and small vertebrate research. Major equipment items for supporting small vertebrate research included a holding unit, cages, several kits, a dissecting microscope, a ventilation unit, and a water tank. The full equipment list shown in Table 2-4 includes items selected to encompass all research areas listed in the NASA guidelines, with greatest emphasis on the high priority (Group 1) areas. The laboratory is equipped with the automated potentiometric electrolyte analyzer for inflight blood and urine analyses plus the blood sample processor centrifuge to prepare these fluids for subsequent ground analyses. The centrifuge includes a head adapter for centrifugation of small animal blood samples as well as human samples. Breadboard drawings at the assembly and component level were prepared for this COL.

3.3 FINAL MSI COL CONCEPTUAL DESIGN

For MSI research, the layout selected by NASA for conceptual design evaluation emphasized basic audio-visual measurements capability. Major equipment included a color video camera, photographic equipment, and a video tape recorder. Such equipment could be used to document cargo handling experiments; assembly, deployment, maintenance, and repair experiments; group dynamics experiments; and locomotion and restraint experiments. In each experiment, the COL audio-visual equipment would be used in conjunction with equipment specific to the individual experiments. Storage volume is provided for some experiment-specific equipment in the COL structure, as shown in Figure 3-3. The MSI COL weighs 87.7 kg (193 lb), and occupies about 846 dm^3 (30 ft^3).

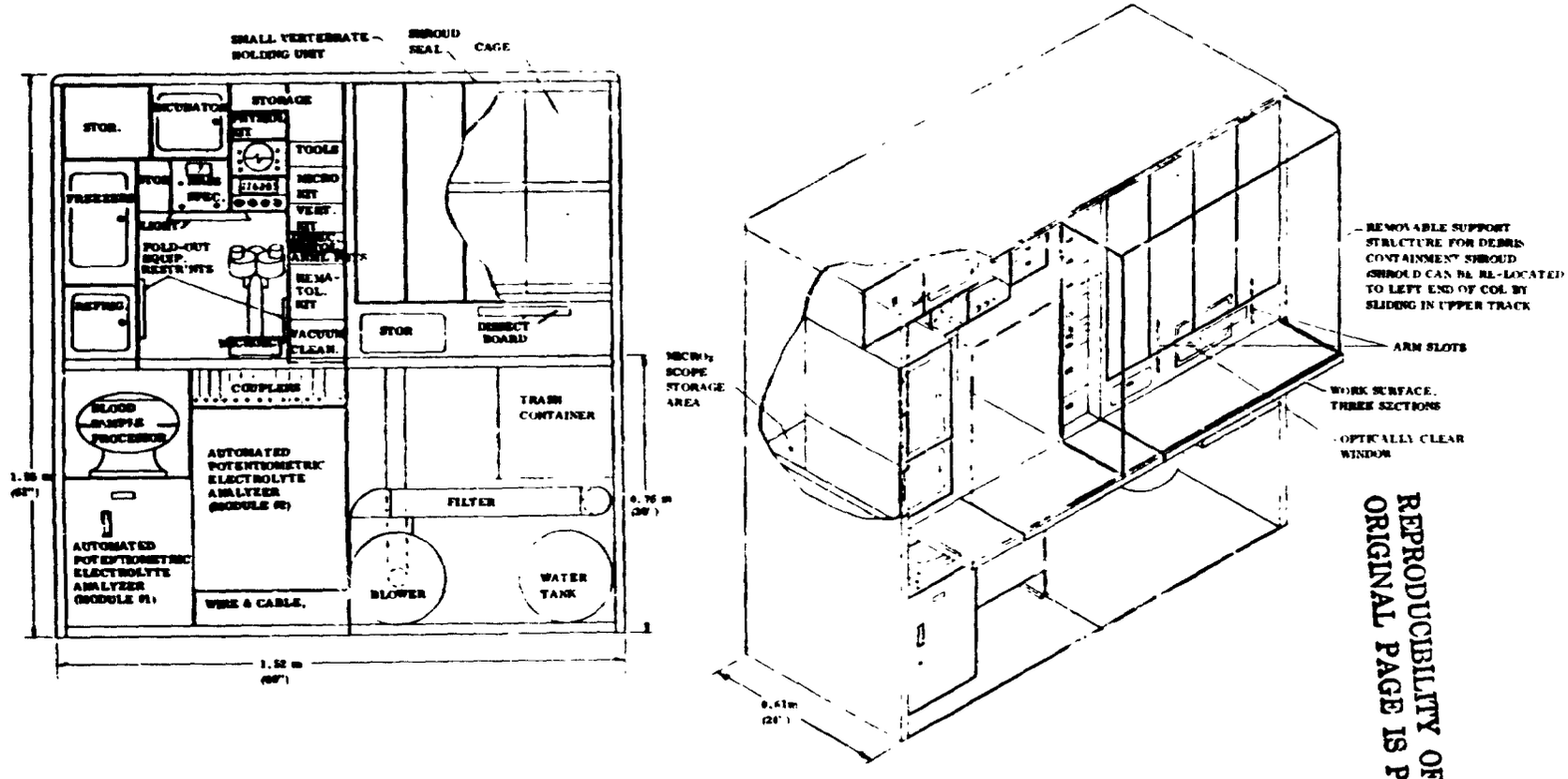

Figure 3-2. Biomedicine/Biology COL Conceptual Design Drawings

3.4 FINAL LSPS COL CONCEPTUAL DESIGN

The final LSPS design concept shown in Figure 3-4 is intended to support all major research areas within the LSPS FPE, including liquid- and gas-handling equipment experiments and crew interfacing equipment experiments. Major equipment includes: 1) cine, video, and still cameras, 2) a gas chromatograph, 3) gas and liquid supply vessels, 4) an infrared gas analyzer, 5) a mass measurement device, 6) a mass spectrometer, 7) a strip chart recorder, and 8) a refrigerator. Gas analyzers and the instrumentation the crew will probably be monitoring during the experiments are contained in the upper module of the COL.

The lower module contains storage areas for less frequently used equipment and fluid storage vessels. It also contains the major lines for interconnection with the various test articles and provides low-temperature coolant, high-temperature coolant, vacuum, liquids, gases, and electrical power. The test article will be accommodated between the upper and lower modules in a space about 1m wide by 0.5m high by 0.5m deep. This test space can be enclosed by an environmental shroud for safety while testing equipment containing toxic or flammable materials and/or fluids. This enclosure would be continuously monitored to detect any equipment leaks immediately and take corrective steps before they could lead to a hazardous condition for the crew or the mission.

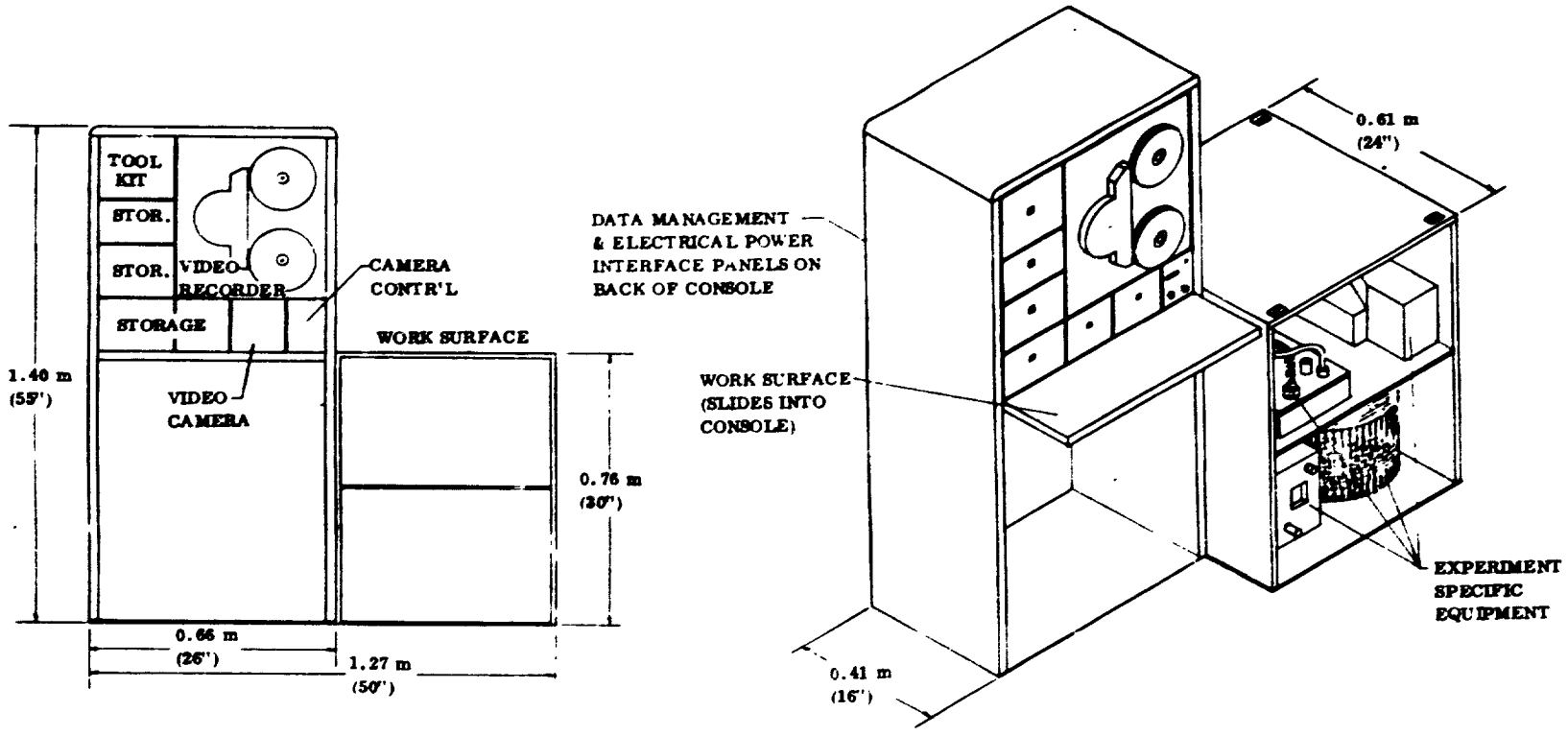

Figure 3-3. MSI COL Conceptual Design

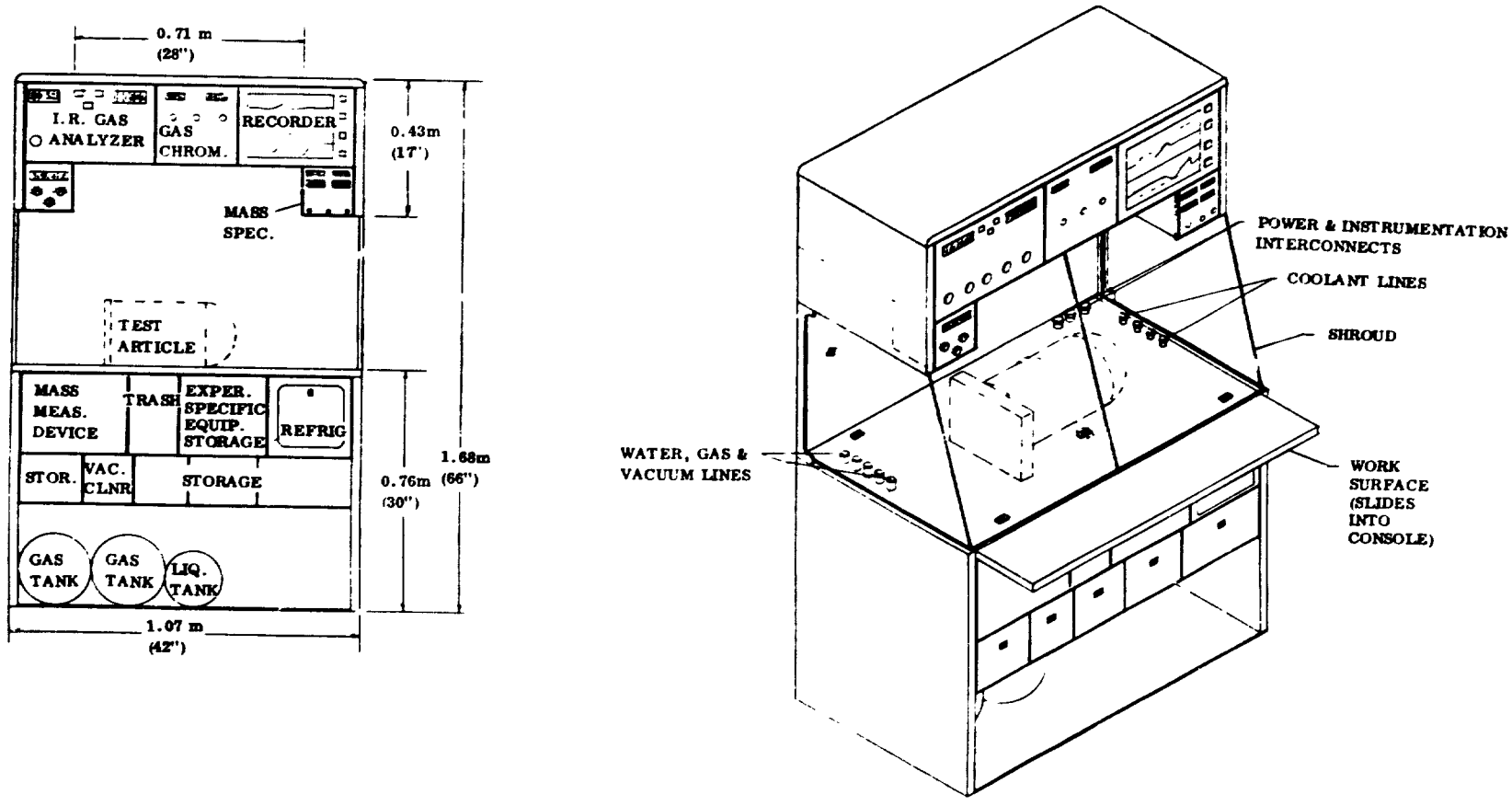

Figure 3-4. LSPS COL Conceptual Design Drawings

SECTION 4

COL INTEGRATION STUDIES

Several integration areas pertaining to the final COL concepts were studied during the program. These included COL requirements for electrical power, data management, Spacelab installation, and special operational considerations and are summarized in this section.

4.1 ELECTRICAL POWER REQUIREMENTS

Electrical power requirements were estimated for each of the final COL (Table 4-1). Power values shown in the table include: 1) average power estimated during the 2-hour use period of the COLs per day, 2) peak power consumed, 3) total energy consumed per day, and 4) average standby power for the 22 inactive hours per day.

The Category A biomedicine/biology COL has the greatest power demands, followed by Category B and C_2 COLs. The equipment item in these COLs that consumes the most power and causes the high demand is the thermoelectric low-temperature freezer. It requires 400 Watts (estimate) when operating.

4.2 COL DATA MANAGEMENT

In estimating data management requirements of the COLs, a philosophy of maximum autonomy and maximum use of manual data-handling techniques was assumed. This was done to minimize the number of interfaces with the centralized command and data management subsystem (CDMS). The resulting independence of the COLs from the Spacelab would add to their flexibility in use.

Very few equipment items require data handling by the central CDMS, and most of these require only a low rate of signal monitoring. Major exceptions are the electrophysiology couplers in the Category A biomedicine/biology COL, which are used in monitoring ECG and EEG signals. These were estimated to generate about 7,000 bits per second of continuous data, which comprises the only significant data output from any COL. The resulting maximum data downlink requirement is about 600 Mbits/day, assuming that all data is downlinked for possible analysis subsequent to the flight. Displays required by the COLs include a cathode ray tube (CRT), numeric readouts, and warning signals to the crew while not attending to the COLs. The video cameras will also require CDMS support for monitoring, recording, and downlinking signals. It was estimated that the biomedicine/biology COL would require such support for about 30 minutes per day, the longest of any COL. Experiment-specific equipment used in conjunction with the COLs will also require some data management support, but the amount of support required cannot be determined yet.

Table 4-1. Electrical Power Summary for Carry-On Laboratories (Preliminary)

LABORATORY	TOTAL POWER OF ALL E.I.'S, WATTS	POWER DURING 2-HR COL USE PERIOD		TOTAL ENERGY CONSUMPTION, W-HR/DAY	AVERAGE STANDBY POWER FOR 22 HRS/DAY, WATTS
		AVERAGE WATTS	PEAK WATTS		
COMBINED BIOMEDICAL/BIOLOGY, CATEGORY A (500-700 LB)	1559	756	1099	6807	241
BIOMEDICAL, CATEGORY B (200 LB)	709	526	634	3865	127
BIOMEDICAL, CATEGORY C_1 (50 LB)	100	25	100	50	0
BIOMEDICAL, CATEGORY C_2	500	425	500	4850	181
BIOMEDICAL, CATEGORY C_3	66	66	66	432	14
LS/PS*, CATEGORY A	490	152	320	2330	92
MSI*, CATEGORY A	309	78	309	155	0

*POWER VALUES DO NOT INCLUDE EXPERIMENT SPECIFIC EQUIPMENT

Data management capabilities of the Spacelab compared with worst-case biomedicine/biology COL data-handling requirements are summarized in Table 4-2. The Spacelab design was in the preliminary stages and information on the CDMS was taken from a recent proposal submitted to ESRO by Messerschmitt, Bolkow-Blohm (MBB). The proposed Spacelab CDMS contains a data bus data acquisition and control system capable of handling payload data at a rate of 1000 kbps, compared to 7 kbps required by the COLs as previously discussed. For video data, the Spacelab will contain a closed-circuit TV monitor and two black-and-white TV cameras. Continuous monitoring capability will thus be available, and the half hour or less required by the COLs should be readily accommodated. The MBB Spacelab planned to have 2 CRTs with alphanumeric display capability, digital readouts, warning lights, audible alarms, two alphanumeric keyboards, and a two-axis joystick controller for TV camera control. These displays and controls would satisfy COL requirements. Computer requirements of the COLs will depend on the specific experiments being conducted, but will probably not exceed the capability of the Spacelab computer, which will have a 48k random access memory and a 1μsec cycle time.

The proposed Spacelab would downlink all data to be preserved via the tracking and data relay satellite (TDRS). Comparing the COL data to be preserved with the TDRS downlink capability shows that the latter is over three orders of magnitude larger than required. The COL TV data can also be downlinked via TDRS, but not simultaneously with digital data. Assuming a 50 percent time-sharing of the link between video and

Table 4-2. Comparison of Carry-On Laboratory Data Management Requirements and Spacelab CDMS Capability

	CARRY-ON LAB REQUIREMENTS	SPACELAB CDMS CAPABILITY*
ON-BOARD DATA HANDLING		
Data Bus Maximum Data Rate, Mbps	0.007	1
Video Monitoring by CCTV, Hrs/Day	< 0.5	Continuous
Displays	CRT, Numeric & Warning	2 CRTs (Alphanumeric Capability), Digital Readouts, Warning Lights & Audible Alarms
Computer: Cycles/sec.	tbd	10^6 (1μs cycle time)
Main Memory Storage, words	tbd	48K
DOWN-LINKED DATA HANDLING		
Digital Transmission to Ground, bits/day	6×10^8 (all data downlinked for preservation)	1.84×10^{12} (assuming 85% availability of TDRS and 50% time-sharing with video data)
Video Transmission to Ground, Hrs/Day	< 0.5 (primarily for purposes of preservation)	10.2 (assuming 85% availability of TDRS and 50% time-sharing with digital downlinked data)

*Control & Data Management Subsystem, based on preliminary studies by Messerschmitt, Bolkow-Blohm (MBB) and General Dynamics/Convair.

digital data and an 85 percent availability of the TDRS link to Spacelab, the values would be as shown in Table 4-2.

In summary, the life sciences COLs will impose a very small load on the Spacelab CDMS compared to its overall capability.

4.3 COL OPERATIONAL CONSIDERATIONS

Several operational aspects of the COLs were considered in this study. These considerations are summarized in the following paragraphs.

4.3.1 GROUND SUPPORT FACILITIES. The COLs are relatively independent and complete laboratory facilities, requiring only electrical power, liquid coolant, vacuum, and data acquisition and processing support equipment. Since the amount of support equipment is nominal, they could be used for ground support experiment procedures if they are designed for both ground and on-orbit operation. COLs could be used to support the research equipment, organisms, and procedures 1) at the principal investigator's laboratory, 2) at the launch site, both before and after flight, and 3) in

the flight vehicle. Making maximum use of the COLs in all three locations would tend to eliminate errors introduced by using different equipment to monitor ground control experiments at each location.

4.3.2 BIOMEDICINE/BIOLOGY COL OPERATIONS. The biomedicine/biology COL presents more potential operational problems than the LSPS or MSI COLs because it contains living organisms and requires control experiments to be conducted on the ground for comparison of results. Mission preparation activities for biological research will include determination of 1) experiment/flight compatibility using NASA flight simulators, 2) experiment protocols, and 3) baseline data on ground control organisms and the organisms intended for flight. These activities could take up to 1 to 2 years, depending on the experiment being prepared. The COLs should be used to support mission preparation activities as much as possible.

Following mission preparation, the organisms and the applicable research equipment would be transported to the launch site and held until launch. This could also be done using the COLs. While the organisms were being transported between facilities, however, the COL would require support in terms of electrical power and data monitoring. This would be provided by the bioexperiment support and transfer unit (BEST) described in the preceding task C and D study on the Dedicated and Shared Life Sciences Laboratories. As a self-contained unit for support of organisms in transit, the BEST would provide structural support, vibration isolation, electrical power, and air purification provisions for the organism holding units during transport.

Various ground support and flight preparations will occur at the launch site. Examples include the attachment of biosensors, checkout of electronic equipment, and checkout of the supporting subsystems aboard the Spacelab. During the last several hours of countdown, the organisms would be loaded on board the Spacelab and launched. Following the orbital research period, organisms may be returned to earth, removed from the Spacelab, and transported to the launch site holding area or the principal investigator's biolaboratory. The mission scenario for bioexperiments is shown in Figure 4-1.

4.3.3 COL CONSUMABLES AND REFURBISHMENT. Consumables on all COLs affect weight as a function of mission duration and the refurbishment necessary on the ground between flights. The total weight difference between the 30- and 7-day COLs is 25 kg (55 lb) for the biomedicine/biology COL, 21.7 kg (48 lb) for the LSPS COL, and negligible for the MSI COL. Refurbishment procedures include replacing filters, batteries, lamps, adsorbents, and kit items. Several equipment items will require cleaning, repackaging, and refilling, and many would undergo a general checkout prior to being committed to a subsequent flight.

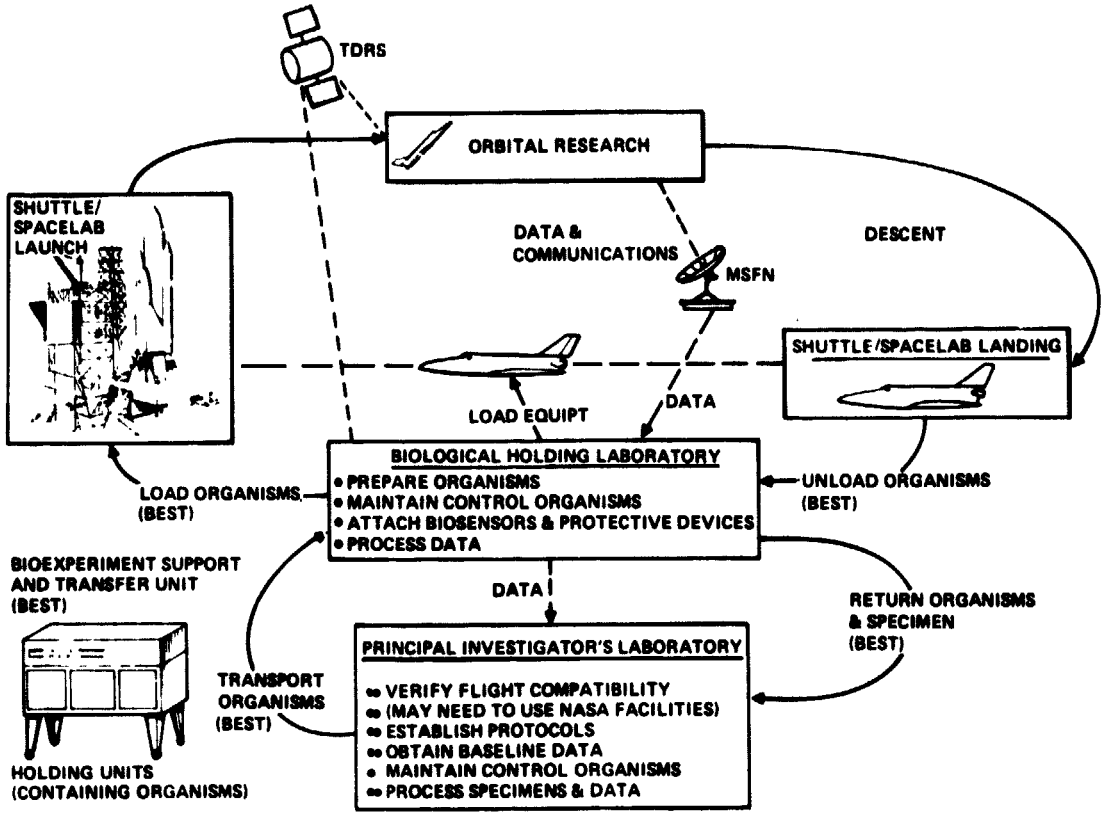

Figure 4-1. Bioexperiment Mission Scenario

4.3.4 INTERFACE SUMMARIES. Overall pertinent interface data for each COL was summarized in tabular form. An example for the biomedicine/biology Category A COL is shown in Table 4-3.

Table 4-3. Summary of Category A Biomedicine/Biology COL Interfaces

INTERFACE AREA	REQUIREMENTS
A. SHUTTLE	A. CATEGORY A LABS ARE NOT LOCATED IN THE SHUTTLE CREW COMPARTMENT.
B. SPACELAB	B. COL IS LOCATED IN PRESSURIZED AREA TAKING 1.52 METERS OF WALL SPACE. APPROXIMATE ENVELOPE IS 1.52 WIDE × 1.55 HIGH × 0.61 DEEP.
C. STRUCTURAL	C. CONCEPTUAL DESIGN INDICATES PORTABLE CONSOLE COMPRISED OF 4 MODULES TOTALING 261 KG. FLOOR & BACK STRUCTURAL ATTACHMENTS REQUIRED DURING LAUNCH-ORBIT-REENTRY.
D. ELECTRICAL POWER (ENERGY)	D. PEAK POWER: 1099 WATTS - AVERAGE POWER: 756 WATTS FOR 2 HOUR OPERATION. ENERGY CONSUMPTION: 6807 WATT-HRS/DAY.
E. CREW . :S/LSS	E. DURING MAN-SURROGATE MISSIONS, THE VERTEBRATE HOLDING UNIT TAKES IN 623 DM^3 (22 CFM) OF AMBIENT SPACELAB AIR & DISCHARGES THE SAME AMOUNT BACK INTO THE SPACELAB AFTER FILTERING TO REMOVE PARTICULATE MATTER & ODORS.
F. THERMAL CONTROL	F. THE AVERAGE HEAT REJECTED TO THE AIR, BASED UPON ELECTRICAL POWER, IS 132 WATTS DURING 22 HOUR STANDBY AND 356 WATTS DURING THE 2 HOUR USE PERIOD HEAT REJECTION TO THE COOLANT LOOP IS 400 WATTS FOR 8 HOURS EACH DAY. THE COOLANT IS REQUIRED FOR THE LOW TEMPERATURE FREEZER AT 150 KG/HR AT 7°C.
G. COMMAND & DATA MANAGEMENT SUBSYSTEM (CDMS)	G. THE SPACELAB PROVIDES ALL THE CDMS SUPPORT NEEDED FOR THE CARRY-ON LAB. ESTIMATED CONTINUOUS DATA BIT RATE IS 7,042 BPS. DOWNLINK REQUIREMENTS ARE 6177 KBITS/DAY
H. CONSUMMABLES	H THE CONSUMMABLES ARE BASED UPON A 30-DAY MISSION. THE VERTEBRATES REQUIRE FOOD, WATER, FILTERS, & WASTE PADS. THE ESTIMATED WEIGHT IS 14 KG. DURING REFURBISHMENT THE VARIOUS KITS WILL REQUIRE REPLACEMENT OF MATERIAL SUCH AS FLUIDS & EXPENDABLE STERILE ITEMS ESTIMATED AT 15 KG CALIBRATION FLUIDS & REAGENTS ARE REQUIRED FOR THE ELECTROLYTE ANALYZER & ARE ESTIMATED AT 4.7 KG SEVERAL OTHER MINOR CONSUMMABLES PLUS THE ABOVE BRING THE TOTAL EXPENDABLES FOR THIS COL TO APPROXIMATELY 35 KG FOR 30 DAYS.
I. OPERATIONAL/MISSION	I. THIS COL REQUIRES THE SPACELAB CREW FOR OPERATION, BOTH IN THE MODE OF OBSERVER AND SUBJECT. BECAUSE OF THE LIVE ORGANISMS ON BOARD THIS LABORATORY, GROUND BASED SUPPORT REQUIREMENTS AT THE LAUNCH AND LANDING FACILITY INCLUDE ORGANISM HOUSING, ECS/LSS, DATA ACQUISITION & ELECTRICAL POWER. A BIOLOGICAL EXPERIMENT SUPPORT AND TRANSFER UNIT (BEST) IS AN INTEGRAL PART OF THIS SUPPORT REQUIREMENT (SEE REFERENCE 1 FOR "BEST" DETAILS). THE INTERACTION OF COMPETING RESEARCH PAYLOADS FOR ON-ORBIT POWER, DATA HANDLING, THERMAL CONTROL, ETC., MUST BE DETERMINED ON AN INDIVIDUAL BASIS; THEREFORE, NO STATEMENTS AS TO COMPATIBILITY CAN BE MADE AT THIS TIME.

SECTION 5

LABORATORY SCHEDULES AND COST ANALYSIS

During the COL scheduling and cost activities, a low-cost methodology was used to establish individual COL equipment item costs. This approach allowed consideration of equipment that was commercial off-the-shelf, modified commercial, laboratory prototypes, etc., significantly lowering the estimated COL costs. These costs included estimates for nonrecurring development, recurring production, and recurring operations. COL costs are summarized in Table 5-1. Costs for all final COL concepts were estimated, based on independent development. In addition, two sequential development cases were costed. Cost estimates were based on the design and schedule information available at the time the study was conducted.

Table 5-1. COL Cost Summary

CARRY-ON LABS	INDEPENDENT DEVELOPMENT COSTS		
	NON-REC	REC-PROD	TOTAL
CAT A - BIOMED/BIOLOGY	$5023K	$586K	$5609K [1]
CAT A - MSI	437	139	576
CAT A - LS/PS	1737	324	2061
CAT B - BIOMEDICINE	1142	138	1208
CAT C1 - BIOMEDICINE	194	84	278
CAT C2 - BIOMEDICINE	179	22	201
CAT C3 - BIOMEDICINE	149	23	172

[1] RECURRING OPERATIONS = $613K/YR @ 2 FLIGHTS/YR. (12 YEAR PROGRAM COST = $5609K + $7356K = $12,965K)
[2] TOTAL BASED ON INDEPENDENT DEVELOPMENT

CARRY-ON LABS	SEQUENTIAL DEVELOPMENT COSTS		
	NON-REC	REC-PROD	TOTAL
EXAMPLE A			
1. DEVELOP CAT C1, C2, & C3	$522K	$129K	$651 K
2. DEVELOP CAT B - BIOMEDICINE	894	138	1032
3. DEVELOP CAT A - BIOMED/BIOL.	4347	586	4933
			Σ $6616K ($7540K) [2]
EXAMPLE B			
1. DEVELOP CAT A - BIOMED/BIOL.	$5023K	$586K	$5609K
2. DEVELOP CAT B - BIOMEDICINE	587	138	725
			Σ $6334K ($6889K) [2]

5.1 BIOMEDICINE/BIOLOGY COL DEVELOPMENT SCHEDULES

A development schedule and funding requirements were generated for the Category A biomedicine/biology laboratory (Figure 5-1). The other COL concepts are less complex, and their schedules would be shorter. Figure 5-1 does not include any contingency time. The development is paced by the first flight date of April 1980 as specified by NASA.

Two classes of equipment items were identified. The first class is the supporting research and technology (SRT) items, which include the common holding unit and its

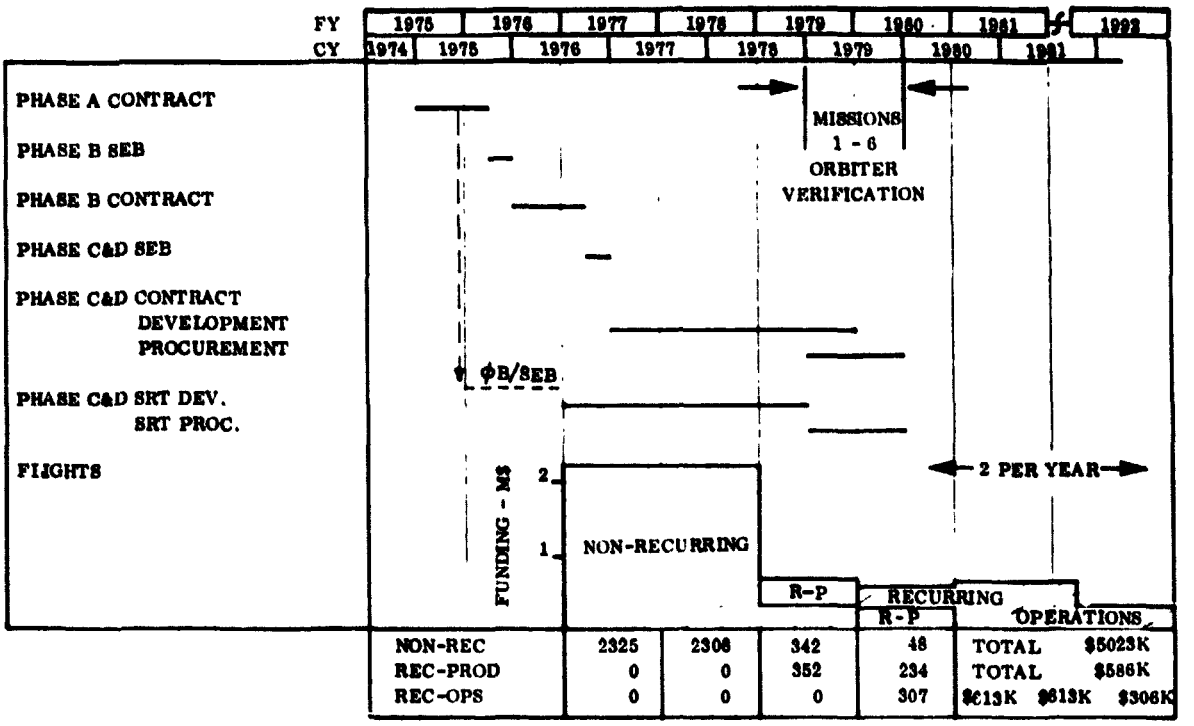

Figure 5-1. Biomedicine/Biology COL Development Schedule and Funding

cages. These items exhibit the highest development risk and require a 2.5-year development program as well as extensive evaluation in the principal investigators' laboratories. It was assumed that the SRT requirements and planning can be established before the end of the COL Phase A Study, enabling initiation of a SRT Phase B activity. This approach satisfies the time requirements of SRT development prior to the flight date. The second class includes all other equipment items. The longest development times were 2.5 years, and this time span was selected for development of all non-SRT equipment. The procurement phase was assumed to be initiated six months before completion of the development phase for all such equipment. This time is necessary to permit integration installation, and checkout of the COL in the Spacelab.

5.2 COST ANALYSIS

A cost model using a work breakdown structure (WBS), including categories of hardware, services, and other cost tasks, was developed for the COLs. The model includes at set of individual equipment item cost estimating relationships (CERs), cost factors, or point estimates. The model also established a mathematical procedure for proper accumulation of the individual elements, together with overall program or mission factors such as operational lifetime, number of launches, etc. The model was used to organize the procedures for determining all individual costs, making up the total COL program cost.

The cost methodology for the individual equipment items in each COL was tailored to obtain the highest confidence cost estimate with the information available. Table 5-2 shows the six methods of costing used and the percentage of the items included under each. A significant portion (33 percent) of the items were costed based on the Space Shuttle Payload Development Activity (SSPDA) study. During this activity, CERS for low-cost Spacelab payloads were developed and in many cases were directly applicable to the COLs.

Table 5-2. COL Cost Estimating Techniques

PERCENT OF ITEMS	COSTING METHODS
33	BASED ON SSPDA DEVELOPED CER'S
25	BASED ON UNOFFICIAL NASA SKYLAB COSTS
19	BASED ON VENDOR CATALOG OR TELECON QUOTES
10	BASED ON ENGINEERING ESTIMATES
6	BASED ON UNOFFICIAL NASA COST DATA FOR PROBRAMS OTHER THAN SKYLAB
7	BASED ON DESIGN MANLOADING & PARAMETRIC ANALYSIS

The second highest percentage of items was estimated based on unofficial Skylab cost information. The majority of these items included kits (17 percent), whose costs were estimated based on Skylab experience with the inflight medical support system kit development. Other costing methodology involved obtaining vendor catalog costs and vendor telecon quotes for modified commercial equipment. The remaining equipment item costs (23 percent) were based on engineering estimates, NASA cost data other than Skylab, and design manloading and parametric analysis.

The resulting total costs for the COLs shown in Table 5-1 are composed of many individual cost elements in addition to the equipment item costs. Ground rules and assumptions used in obtaining these total costs are presented in Volume II. Cost elements included in the analysis, as well as those specifically excluded, are shown in Table 5-3.

5.3 COST REDUCTION GUIDELINES

As a result of the cost studies performed on the COLs, it became apparent that there are several cost reduction areas that should be emphasized (in addition to making maximum use of commercial equipment technology). The first and most important is the use of cost performance trade studies, together with a design-to-cost approach. Historically, performance requirements for a design have been established with minimum if any consideration for their effect on cost. As a result, large cost penalties are incurred for small or unnecessary increases in performance. In the design-to-cost

Table 5-3. Summary of Cost Elements

INCLUDED ITEMS	EXCLUDED ITEMS
NON-RECURRING DEVELOPMENT	
- DESIGN & DEVELOPMENT	NASA INTERNAL MANAGEMENT
- QUALITY ASSURANCE & RELIABILITY	PRINCIPAL INVESTIGATOR SUPPORT
- SYSTEM ENGINEERING	
- MISSION ANALYSIS	
- COL SYSTEMS TEST	EXPERIMENT SPECIFIC EQUIPMENT
- INTEGRATED SPACELAB TEST	
- INTEGRATION	GROUND-BASED LAB ARTICLES FOR CONTROL EXPERIMENTS
- GSE	
- INITIAL SPARES	TRAINING ARTICLES
RECURRING PRODUCTION	BREXPERIMENT SUPPORT & TRANSFER UNITS
- MANUFACTURE	BACKUP LABS
- QUALITY CONTROL	
- ACCEPTANCE TEST	GROUND MOCKUP
- SUSTAINING ENGINEERING	
	DEDICATED SPACELAB COST
RECURRING OPERATIONS	
- CONSUMPTION SPARES	SPACE SHUTTLE USER CHARGES
- REFURBISHMENT	
- LAUNCH OPERATIONS	PHASE A & B COSTS
- MISSION OPERATIONS	
GENERAL AND ADMINISTRATIVE	FLIGHT CREW COSTS
MANAGEMENT & ADMINISTRATION	GROWTH OR CONTINGENCY COSTS
FEE	FACILITIES COSTS

approach, a balance between performance and cost is accomplished. To achieve a low cost program, the marginal cost increase to achieve a given change in performance must be known.

Figure 5-2 shows a general cost-performance relationship with thresholds and goals established. These thresholds and goals must be set by the cognizant engineers and scientists so that configurations can be analyzed to determine a cost/performance relationship. To control total program costs, a design-to-cost approach is recommended for use during the development and production phase as a means of cost control. These cost control approaches should include limitations on cost escalation, with specific items or systems subject to removal from the program if the price rises beyond set limits. This type of costing approach has been successful in military programs and is being incorporated into the European Spacelab development program.

One area that resulted in high costs on past programs is frequent design criteria iterations. This often causes redesign and retesting, with consequent schedule and cost impacts. Once established, design criteria should not be changed even if some performance degradation will result. If interface parameters are not firm until late in a program, there will be a similar effect resulting in large cost increases. These criteria, therefore, should be firmly established early in the program and changes should be limited.

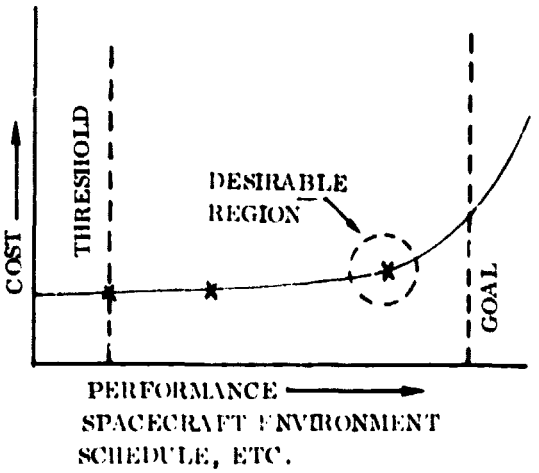

Figure 5-2. Cost Performance Relationship

Significant cost reductions can be achieved in the area of reliability by relaxing requirements where crew safety is not involved. Payload reliability requirements can be further reduced because of the many flight opportunities in the mission and the capability to perform onboard maintenance. The use of off-the-shelf and custom commercial equipment with inherent high reliability will also tend to reduce costs associated with reliability.

Commonality of equipment associated with the various scientific disciplines scheduled for the Shuttle/Spacelab operation provides an opportunity for cost savings. Equipment such as cameras and recorders are likely candidates for this cost reduction.

SECTION 6

CONCLUSIONS

This study, the third in a series of pre-Phase A studies, is the final element of NASA's initial planning for life sciences space research in the 1980 time frame. The basic philosophy of these three programs (NAS8-26488, NAS8-29150, and NAS8-30288) has stressed the importance of 1) valid research, 2) research flexibility, and 3) cost effectiveness. Scientific requirements have been a controlling factor in all program decisions, and scientists have been involved in the program since the beginning so that their requirements could direct the designs. To provide the research flexibility and cost effectiveness required of a long term (12+ years) program, modular hardware design concepts using common equipment have been stressed.

The life sciences COLs provide a wide range of research capability from the small Category C to the large Category A concepts. The Category A COLs are responsive to all research areas specified in the NASA guidelines, even those with the lowest specified priority. The COL characteristics, both in terms of research capability and size, provide a great deal of flexibility to respond to unscheduled as well as scheduled flight opportunities. Table 6-1 summarizes the major characteristics of the seven COLs studied. The NASA weight guidelines were never violated, and the electrical power demands do not appear excessive. The volume of the small Category C COLs is compatible with the stowage compartments of the Shuttle Orbiter, and the large COLs are easily accommodated in the Spacelab.

6.1 SUPPORTING RESEARCH AND TECHNOLOGY

The pacing hardware item required to support the COLs is associated with the biomedicine/biology concept: the common holding unit for organisms. Since this unit must provide a suitable environment for a broad range of biological organisms, it must be designed to meet different experimenters' needs while satisfying each experimenter's requirement to conduct scientifically valid research. These holding units were required in all COL concepts performing man surrogate or basic biology research. Accordingly, the potential for continued and frequent use of these units is high.

6.2 RECOMMENDATIONS

A Phase A program to support life sciences space research is recommended. The results of this and previous life science payload studies provide a firm base for future Phase A activity.

Table 6-1. Summary of COL Characteristics

CARRY-ON LAB CONCEPTS	WEIGHT[1] KG (LBS)	POWER-WATTS PEAK	POWER-WATTS AVG	VOLUME[2] DM^3 (FT^3)	COST $k DEV	COST $k UNIT	COST $k TOTAL
CATEGORY A BIOMEDICINE/BIOLOGY	261 (575)	1099	756	1440 (51)	5023	586	5609
CATEGORY A MSI	87.7 (193)[3]	309	78[3]	846 (30)	437	139	576
CATEGORY A LSPS	163 (360)[3]	320	152[3]	1090 (39)	1737	324	2061
CATEGORY B BIOMEDICINE	84.7 (187)	631	526	380 (13)	1112	138	1208
CATEGORY C1 BIOMEDICINE	19.5 (43)	100	25	234 (8.3)	194	84	278
CATEGORY C2 BIOMEDICINE	22.9 (50)	500	425	93 (3.3)	179	22	201
CATEGORY C3 BIOMEDICINE	19.0 (42)	66	66	78 (2.8)	149	23	172

(1) INCLUDES RESEARCH EQUIPMENT & CONSOLES

(2) INSTALLED ENVELOPE VOLUME

(3) DOES NOT INCLUDE EXPERIMENT SPECIFIC ITEMS

Early start of Phase A program is required to support planned missions in 1980. The present mission model is based on the first COL in April 1980 and the first dedicated laboratory in August 1980.

Since the mission models and schedules do not include contingency time, an early start of the SRT item development (common holding unit) is necessary to support principle investigator baseline activity prior to flight.

Design-to-cost approach guidelines for future hardware procurement should be established.

PART II

TASK ELEMENT 2

DEDICATED 30-DAY LABORATORY PROGRAM COSTS

SECTION 1

INTRODUCTION

This study task (Element 2) was performed to update the costing accomplished during the Task C&D effort of the previous contract, NAS8-29150. An overall costing methodology was developed to cover both the COL and Dedicated Laboratory requirements. Figure 1-1 is an overview showing the flow of costing activity for the dedicated laboratory.

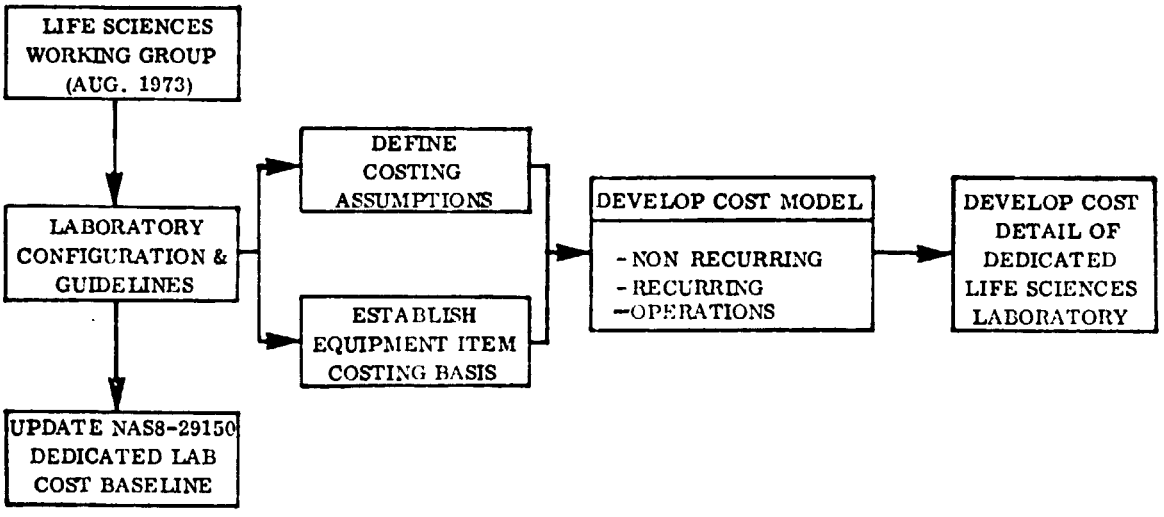

Figure 1-1. Costing Activity Overview

As stated above, the costs developed for the 30-Day Dedicated Laboratory were based on the same techniques used for the COL. These were summarized in Part I, Section 5 of this volume. The equipment item costing base was the same as that presented in Part I, Table 5-2. Total costs were composed of many individual cost elements. COL costing assumptions of included and excluded cost elements (Part I, Table 5-3) are basically the same as those used for the Dedicated Laboratory.

The foundation of the cost model was the (≈120) individual equipment item (EI) cost elements that made up the total laboratory capability. In addition, the model established a mathematical procedure for the proper accumulation of these individual cost elements together with the overall program or mission factors such as operational lifetime and number of launches. This model was used to organize the procedures for determining all individual cost "pieces" making up the total Dedicated 30-Day Lab program costs.

Results of the Dedicated 30-Day Lab costing activity are summarized in the following sections of this volume and detailed in Volume IV, the appendix.

SECTION 2

COSTS AND SCHEDULES

Costs for two dedicated laboratory concepts were estimated, including the primary Biomedical Emphasis Laboratory and a Bioscience and Technology Laboratory. The Bioscience and Technology Laboratory added research capability in man/systems integration (MSI) and life support and protective systems (LSPS). The costs generated include estimates for nonrecurring development, recurring production, and recurring operations. These estimates do not include such major elements as the space shuttle vehicle, the Spacelab, or principal investigator costs.

Costs for a Biomedical Emphasis Laboratory and a Δ cost to provide a Bioscience and Technical Laboratory are shown in Table 2-1.

Table 2-1. Laboratory Cost Summary (K$)

	Non-Recurring Development	Recurring Production	Recurring Operations	Total
Biomedical Emphasis	19,137	2,809	35,425	57,371
Bioscience and Technology Laboratory Cost Δ	2,318	358	3,416	6,092

The most significant cost element is the recurring operations of over $35 million. Within the recurring operations cost element, the refurbishment and updating amounts to over 70 percent of the total.

A Dedicated Laboratory development and operational schedule was established for the Biomedical Emphasis Mission only. The development schedule shown in Figure 2-1 is based on the first flight date of August 1980, and includes no contingency time. Laboratory funding spread is shown in the lower portion of the figure. Recurring operations costs are based on a 12-year operational program with a total of 28 flights.

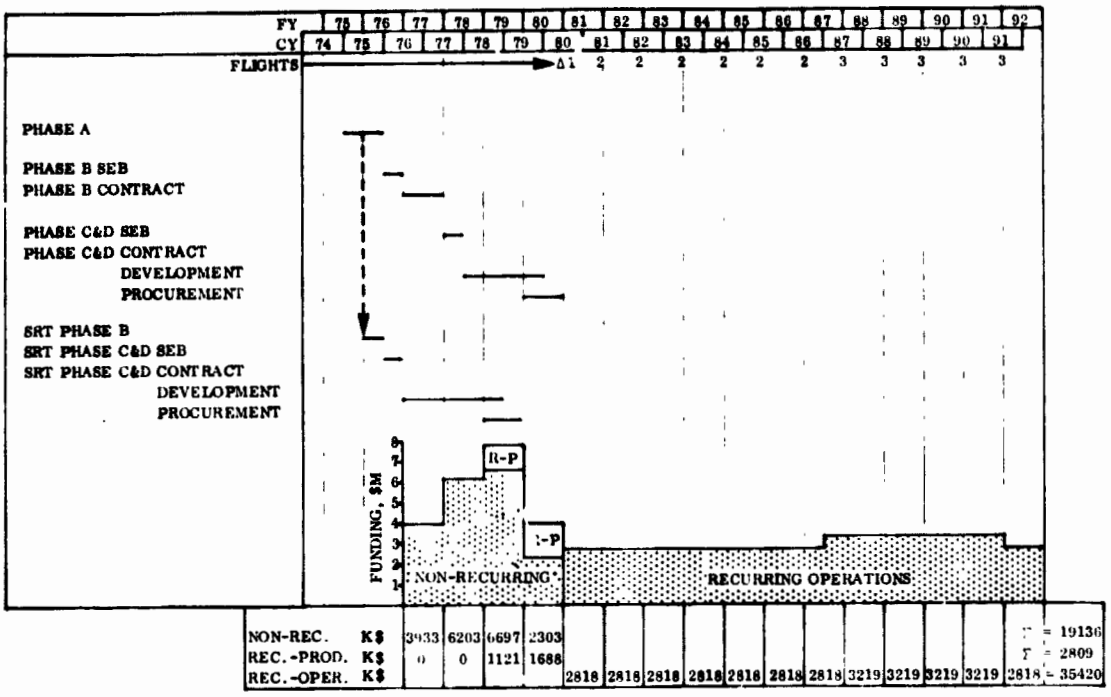

Figure 2-1. Dedicated Biomedical Emphasis Lab Schedule and Funding

SECTION 3

SELECTED COST DETAILS

3.1 SUPPORTING RESEARCH AND TECHNOLOGY EQUIPMENT ITEMS

The program schedule (Figure 2-1) indicates that the supporting research and technology (SRT) areas impact the scheduled development time of the Dedicated Laboratory. Considering the total number of equipment items within the laboratory, only a few are critical SRT items. These SRT items exhibit the highest development risk and some, like the common holding unit and its inserts, require extensive evaluation in the principal investigator's (PI's) laboratory. Initiation of SRT Phase C&D is required approximately 1-1/2 years before the other equipment items. To accomplish this within the available time span, SRT Phase B must be initiated before the end of the Phase A study for the total Dedicated Laboratory. The SRT items and their indicated development time are:

Common Holding Unit, Inserts and Camera Drive System	30 months
Freezers and Refrigerators	24 months
Monkey Cages	30 months
Centrifuge	30 months
Environmental Control System	30 months

3.2 NON-SRT EQUIPMENT ITEMS

An additional class of equipment items (EIs) represents all those not in the SRT category. The development time of each equipment unit (EU)* was estimated based on its longest EI development time. Total Phase C&D development time span is two years. Table 3-1 shows the development time spans of the different EUs. To permit checkout and installation time for the laboratory, the procurement phase is initiated six months before completion of the development phase for all non-SRT items. A minimum risk is anticipated by initiating procurement prior to completion of the development phase because the last development tasks represent EU and Life Sciences Lab System Tests. The changes that would impact production are expected to be at a minimum during this phase of development.

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*A grouping of functionally related equipment items; i.e., EU 5 (Biochemical and Biophysical Analysis Unit) contains analytical instrumentation to perform required inflight analyses.

Table 3-1. EU Development Time Span (Assumes 1 January 1978 Start)

Development Times			
6 Months	12 Months	18 Months	24 Months
EU-1	EU-3	EU-2	EU-4
EU-6/7	EU-40/41/42		EU-5
EU-60/61	EU-50/51/70	EU-80	EU-26
EU-23	EU-91/93		EU-12/31

3.3 HIGH COST ITEMS

Table 3-2 lists all equipment items with nonrecurring development costs above $100K, and Table 3-3 lists all equipment items with recurring production costs above $50K. All costs shown are only at the EI level, and do not include EU level costs such as system test, system engineering and integration, ground support equipment, M&A, and fee.

There are three cost groups for the nonrecurring items. The first includes only the common holding unit. Its cost estimate confidence level is rated as medium high, and no significant cost reduction is possible without changing the scope of the system.

The second group ranges from $615 to $977K. Items in this category have a medium confidence level, and further detailed definition of the design characteristics could reduce costs. The bioresearch centrifuge cost, however, could be increased significantly if the design required a non-stoppable centrifuge approach.

All other items are in the $100 to $200K development cost range. The cost of the majority of these items can possibly be reduced with more detailed definition of the design requirements, as would occur during a Phase A program.

Table 3-3 lists the equipment items with recurring unit cost above $50K. Two groups are apparent, those with costs below $100K and the bioresearch centrifuge with a unit cost of $277K. The centrifuge cost, as discussed above, can be subject to significant change, depending on its further definition. Of the remaining items, about one third of which are GFE, the majority of the costs can be subject to reduction with more detailed definition of design and production requirements.

3.4 SKYLAB EQUIPMENT APPLICABILITY

About one fourth of the Dedicated Laboratory equipment item costs were based on Skylab information. Some of this equipment developed and flown on the Skylab will meet the Life Sciences Laboratory requirements, but a limited amount of hardware

Table 3-2. 30-day Dedicated Laboratory Payload Equipment Items with Non-recurring Costs Above $100K

NO.	EU	EI	NAME	NON-REC.* K$
1	-	99	COMMON HOLDING UNIT	1544
2	23	43	BIORESEARCH CENTRIFUGE	977
3	80	115F	LSS TEST BENCH	670
4	41	28A	CAGE, MONK, MACAC	615
5	5	89	GAS ANALYZER, GC COMPLEX	276
6	91	144C	PSYCHOMOTOR, PERF. CONSOLE	233
7	12	51D	CONT. CONSOLE, EXPMTR.	233
8	40	30A	CAGE, RAT/HAMP/QUAIL	224
9	26	150	RADIATION SOURCE STORAGE	208
10	1	38A	CAMERA, X-Y DRIVE	200
11	60	98A	HOLDING UNIT, PLANT	184
12	5	148	BENCH, GEN. EXP.	118
13	2	63B	DISPLAY KEYBOARD	128
14	4	41	CENTRIFUGE, FRIG. HI-SPEED	124
15	4	81	FREEZER, LOW TEMP.	122
16	4	77B	FREEZER, CRYO	105
17	5	91	GAS ANALYZER, MASS SPEC.	100

*THESE COSTS DO NOT INCLUDE EU LEVEL COSTS, I.E., SYSTEM TEST, SE&I, GSE, M&A, & FEE.

Table 3-3. 30-day Dedicated Laboratory Payload Equipment Items with Recurring Production Unit Costs Above $50K

NO.	EU	EI	NAME	REC-PROD.* SK
1	23	43	BIORESEARCH CENTRIFUGE	277
2	5	91	GAS ANALYZER, MASS SPEC.	100
3	1	38	CAMERA, VIDEO COLOR	100
4	91	144C	PSYCHOMOTOR PERF. CONSOLE	97
5	12	51D	CONT. CONSOLE EXPMTR.	97
6	80	115F	LSS TEST BENCH	86
7	41	28A	CAGE, MONK, MACAC	84
8	4	186	VOLUMETRIC, MEAS. LIQUID	75 (GFE)
9	5	7	GEMSAEC	75 (GFE)
10	26	150	RADIATION SOURCE STORAGE	60
11	-	99	COMMON HOLDING UNIT	55
12	5	85	GAS ANALYZER, AUTO PHYSIO.	50 (GFE)
13	12	153A	ROTATING LITTER CHAIR	50 (GFE)
14	31	76M	ULTRASONASCOPE	50 (GFE)

*THESE COSTS DO NOT INCLUDE EU LEVEL COSTS, I.E., SYSTEMS TEST, SE&I, GSE, M&A, & FEE.

for future use is available. This generally consists of a bonded flight backup unit, qualification units, and training units in the PI's laboratory.

Refurbishment of an available unit was assumed possible, with the remainder of the units providing a backup capability. However, the number of units available for spares is limited. New production of Skylab items was assumed in two categories.

The first includes items manufactured by commercial vendors, and it is considered feasible that the item can be produced again. Given the new low-cost guidelines, the costs will probably be lower than for Skylab and the benefit of any applicable state-of-the-art advancement will be included.

The other category is those items developed and produced by NASA, universities, or prime contractors. Attempting to procure additional Skylab hardware through these will undoubtedly result in significant nonrecurring costs, if feasible at all. The Skylab technical and production team will probably have been dissolved.

In summary, Skylab equipment applicability to the Life Sciences Laboratory must be investigated in detail based on the individual items under consideration. The equipment available will satisfy the requirements for some items, while for others a cost tradeoff to determine the most viable approach is necessary.

SECTION 4

SUMMARY

As a result of cost studies performed on the dedicated laboratories, certain programmatic and technical factors became apparent. The following list describes the more significant considerations.

1. The laboratory development schedule required to support an August 1980 mission is extremely tight and contains no contingency time.
2. Certain SRT areas require that Phase A/B program activity begin in January 1975 and that Phase C&D begin by mid-1976. This would provide SRT equipment items to the PIs for baseline experiments prior to the space mission.
3. The confidence level for the majority of equipment item cost estimates ranges from medium high to medium. This means that the cost estimates at the equipment level would be subject to change when the requirements changed or when equipment definition became more detailed.
4. The major contributor to program costs, about 60 percent, is the recurring operations during the 12-year program.
5. Wraparound cost factors (such as system test, system engineering and integration, M&A, fee, and initial spares) are based on historical data where available and estimated allowances in the other cases. These factors could vary considerably depending on the guidelines used. The cost based on these factors amounted to about 9 percent of the total Dedicated Laboratory cost estimate.
6. Available Skylab equipment can be used very effectively for the Life Science missions. Caution, however, should be exercised with respect to its availability to support a 12-year program.
7. Cost reduction guidelines, as discussed in Part I, Section 5.3, of the COL cost summary, are completely compatible with the Dedicated Laboratory concept.

PART III

TASK ELEMENT 3

DEDICATED 30-DAY LABORATORY DATA MANAGEMENT REQUIREMENTS

SECTION 1

INTRODUCTION

This study task (Element 3) was performed to update the data management subsystem (DMS) study performed in the preceding Life Sciences Payload Definition and Integration Study (Task C & D), NAS8-29150. A brief summary of the previous study is presented in this part.

The Task C & D DMS Study was performed to 1) estimate the data management requirements of the life sciences laboratories and 2) determine whether the Spacelab, in which they were to be housed, contained sufficient DMS equipment for their support. Spacelab was referred to as the Sortie Module in the Task C & D study. At that time, Sortie Module design included a mini-computer, a display and control console, and a digital control unit for controlling signals transmitted serially throughout the laboratory on a data bus that could handle a maximum rate of 1000 kbps. All communications to ground were provided by the Shuttle Orbiter communications system, through the manned spaceflight network (MSFN). Long-term data storage was accomplished by onboard recording using three magnetic tape recorders: one video recorder and two general-purpose analog or digital recorders.

Life sciences laboratory requirements were estimated during Task C & D for three laboratories. The largest was the 30-Day Dedicated Laboratory, which is the subject of this task element. For equipment in the 30-Day Laboratory, the average sampled digital data output rate was about 45 kbps, with a peak rate of about 90 kbps. These rates could be handled readily by the previously proposed Sortie Module data bus, and the resulting data could be stored using the onboard tape recorders. Video data recording requirements, however, were quite large. In addition to those provided by the Sortie Module, three recorders were needed to accommodate the video data. Also, about 1100 kg (2400 lb) of tape were needed for the 30-day mission duration.

SECTION 2

TASK OBJECTIVES

The Element 3 task reevaluated data management requirements of the 30-Day Dedicated Life Sciences Laboratory. This included updating the digital data rates and video requirements to accommodate equipment reductions made by the NASA Life Sciences Working Group subsequent to the Task C & D study. Element 3 was also intended to investigate the need for alternative data-handling techniques. These included the use of manual versus automatic data handling and the use of downlinking versus onboard storage to preserve long-term data. Rather than onboard storage, the current Spacelab concepts use the tracking and data relay satellite (TDRS) for downlinking all data. Therefore, this mode of long-term preservation was the primary consideration in this study. Because of the reduced equipment in the Dedicated 30-Day Laboratory and the increased capability of the current Spacelab command and data management subsystem (CDMS), manual data-handling techniques were not needed from the standpoint of reducing the load on the CDMS. However, the philosophy used in formulating the life sciences laboratory requirements was that of using manual techniques whenever this was compatible with the equipment and such equipment was being attended by a crewman.

SECTION 3

SUMMARY OF RESULTS

Reevaluations of data management requirements and the Spacelab capability are summarized in Table 3-1. A brief description of the Spacelab CDMS capability is presented in Part I, Section 4.2 of this volume. The detail DMS evaluation is presented in the appendix, Volume IV. In summary, the anticipated Dedicated 30-Day Laboratory requirements are well within the planned capabilities of the Spacelab CDMS.

Table 3-1. Comparison of Dedicated 30-day Laboratory Management Requirements and Spacelab CDMS Capability

	DEDICATED 30-DAY LAB REQUIREMENTS	SPACELAB CDMS CAPABILITY*
ON-BOARD DATA HANDLING		
Data Bus Maximum Data Rate, Mbps	0.116	1
Digital Wide Band Storage Rate, Mbps	0.116	50 (hardwired)
Video Monitoring by CCTV, Hrs/Day	<1.5	Continuous
Displays (other than Video)	CRT, Numeric & Warning	2 CRTs (Alphanumeric Capability), Digital Readouts, Warning Lights & Audible Alarms
Computer: Cycles/second	500K } IMBLMS estimates	1000K
Main Memory Storage, words	13K } IMBLMS estimates	48K
DOWN-LINKED DATA HANDLING		
Digital Transmission To Ground, bits/day	2×10^9 (all data downlinked for preservation)	1.84×10^{12} (assuming 85% availability of TDRS and 50% time-sharing with video data)
Video Transmission To Ground, Hrs/Day	1.5 (primarily for purposes of preservation)	10.2 (assuming 85% availability of TDRS and 50% time-sharing with digital downlinked data)

*Control & Data Management Subsystem, based on preliminary studies by Messerschmitt, Bolkow-Blohm (MBB) and General Dynamics/Convair.

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